The value of hydrological ensemble predictions for reservoir inflow management

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H-SAF & HEPEX Workshop – Reading – Nov. 3-7, 2014

The value of hydrological ensemble predictions for reservoir inflow management

- Reservoir management concerns...

  I. operational hydrologists interested in forecasting hazardous events like floods for early warning and reservoir operation (safety & security)

  II. planners searching to optimize the management of water resources systems (uses & conflicts) and to plan system's evolution at different space-time scales (basin/national/regional planning)

Loire River @ Grangent
November 2008
Photo: EDF

The value of hydrological ensemble predictions for reservoir inflow management

- Objective
  - to investigate the benefits of using hydrological ensemble predictions for reservoir inflow management in terms of potential gain to hydropower production
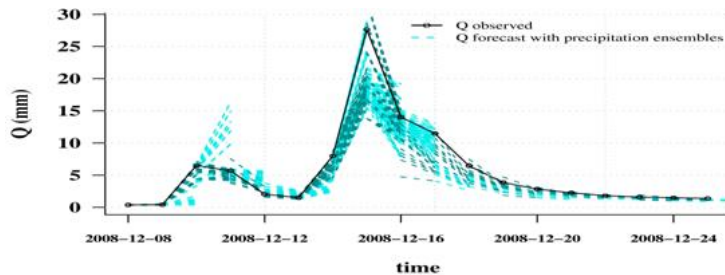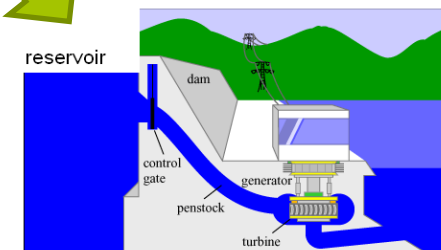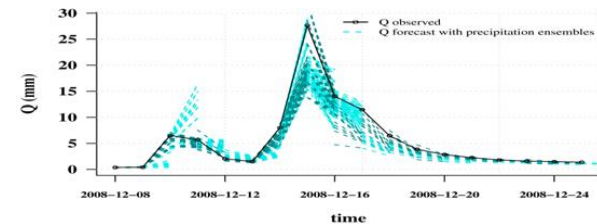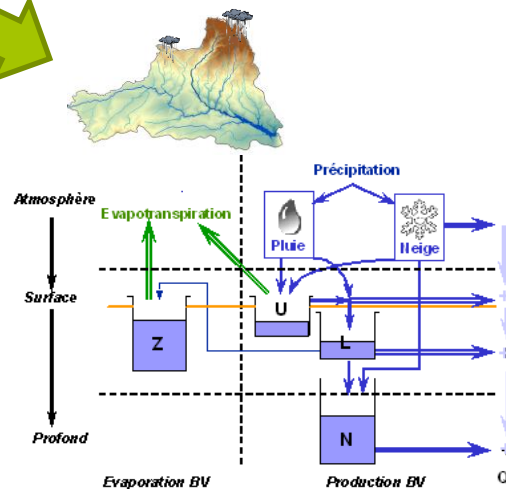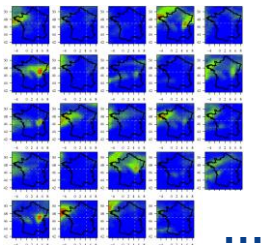

Photo: ENPC

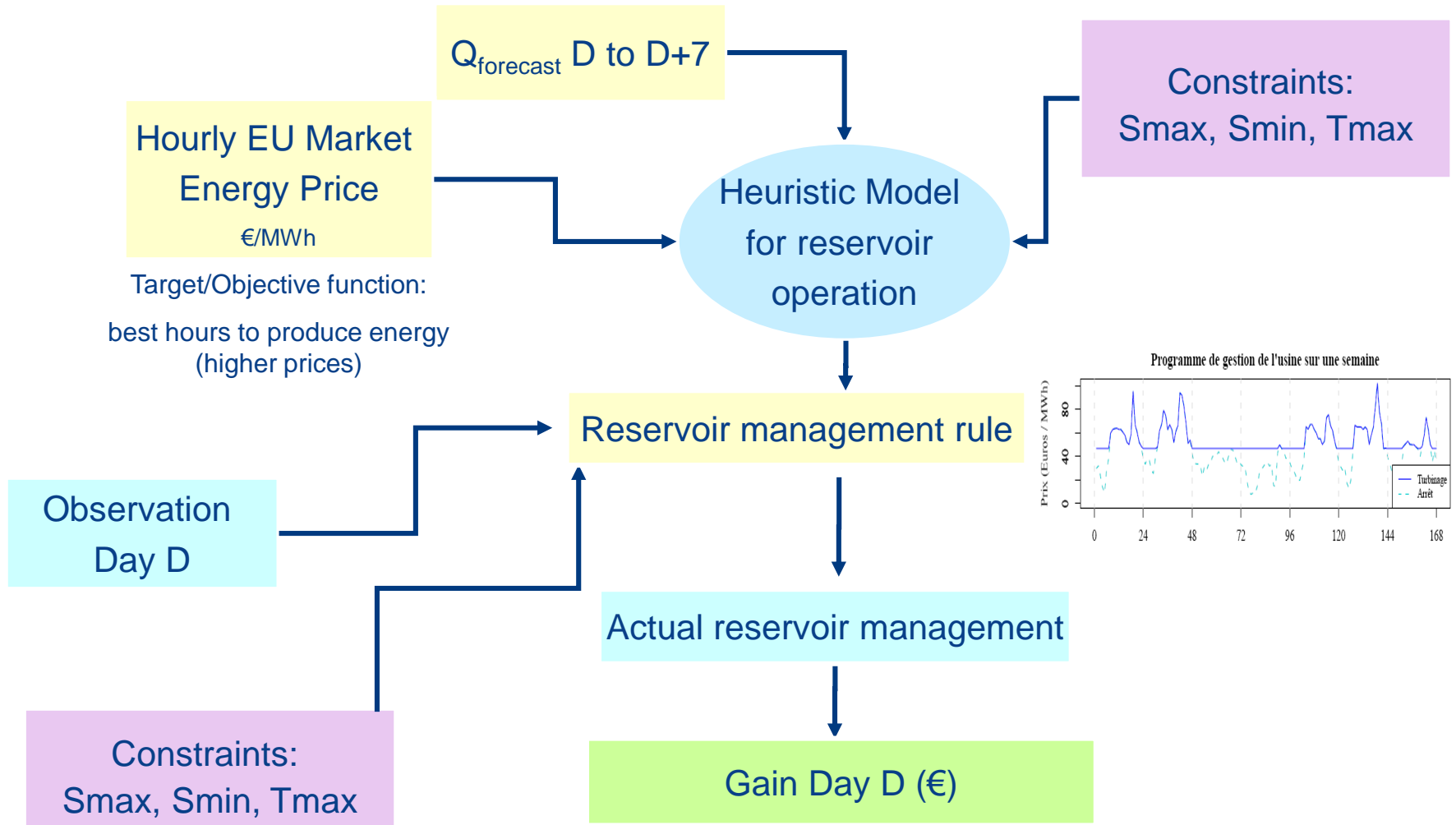*Durance River @ Serre Ponçon May 2008*
Photo: EDF

The value of hydrological ensemble predictions for reservoir inflow management

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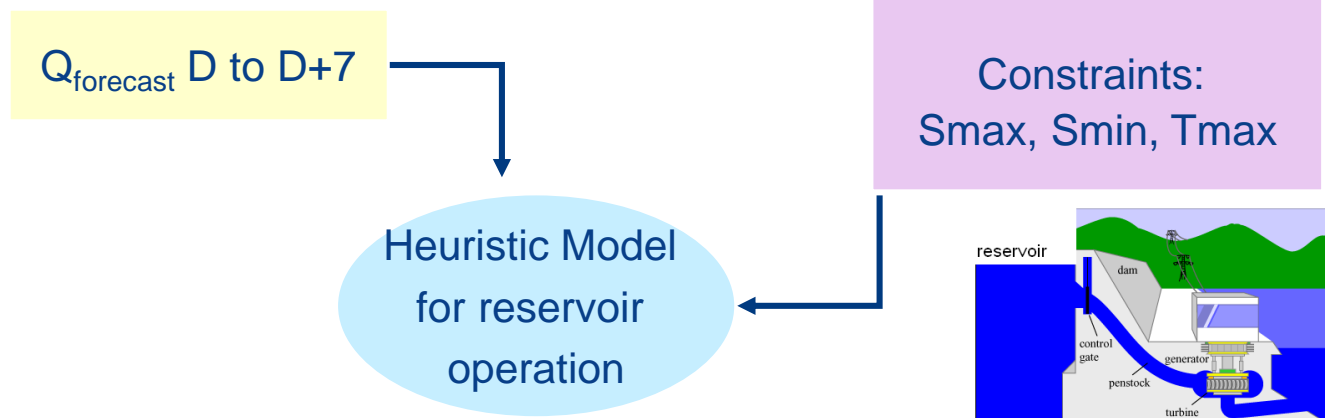 - Hourly EU market energy prices (EPEX SPOT)

4

The value of hydrological ensemble predictions for reservoir inflow management

$Q_{forecast}$ 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

Actual reservoir management

Gain Day D (€)

Programme de gestion de l'usine sur une semaine

The value of hydrological ensemble predictions for reservoir inflow management
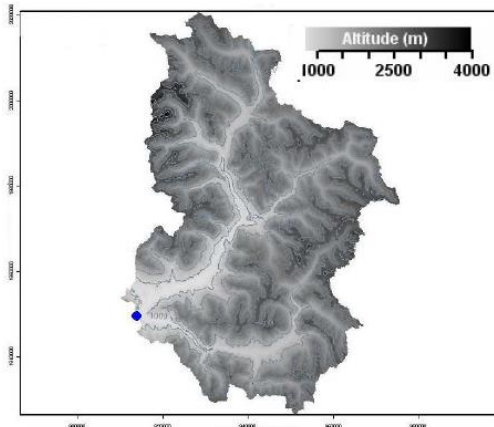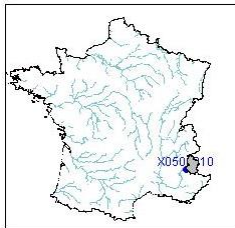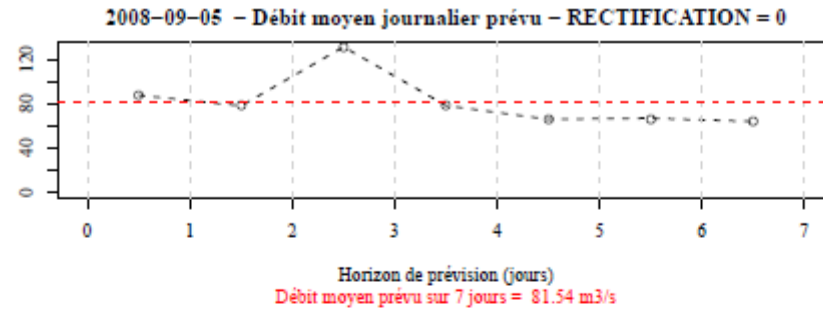
- Modelling of the power systems

    - Hydrological inflows: predictions over French catchments

    - Reservoirs: units of power production described by

        - Storage capacity coefficient (Smax, Smin): in days of mean daily flow of the catchment

        - Turbine capacity coefficient (Tmax): maximum flow capacity (also related to the mean daily flow of the catchment)

$Q_{forecast}$ D to D+7

Constraints:
Smax, Smin, Tmax

Heuristic Model for reservoir operation

reservoir

dam

control gate

generator

penstock

turbine

Results: illustration for one day of single forecast (1/3)

- Sep 5th 2008:

  Predicted inflow to the Durance reservoir for the next 7 days
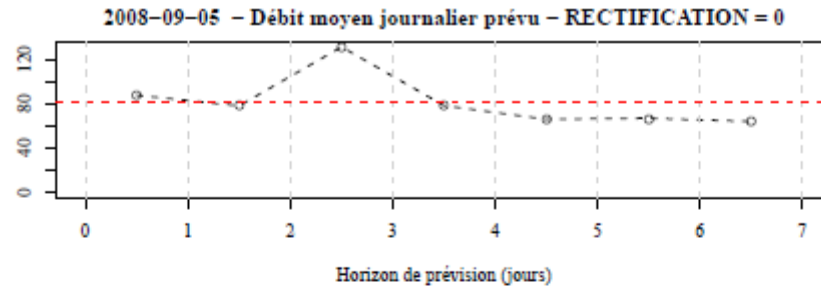

Q (m³/s)

Results: illustration for one day of single forecast (1/3)

- Sep 5th 2008:
  Predicted inflow to the Durance reservoir for the next 7 days

- Energy prices for the week
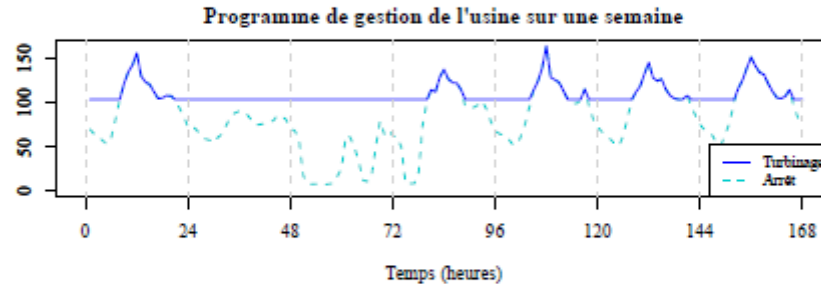
- Turbine capacity = 3 * mean daily flow of the catchment

Q (m³/s)

2008-09-05 – Débit moyen journalier prévu – RECTIFICATION = 0

Horizon de prévision (jours)
Débit moyen prévu sur 7 jours = 81.54 m3/s

PRICES

Programme de gestion de l'usine sur une semaine

Turbinage
Arrêt

Temps (heures)
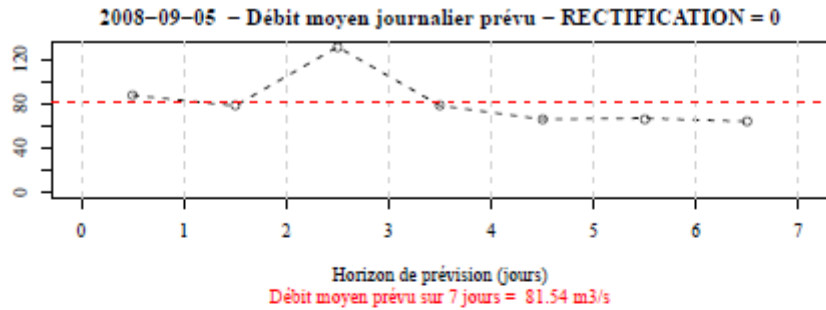Prix seuil (s) E/MWh = 103.81

Indicator: turbine on/off

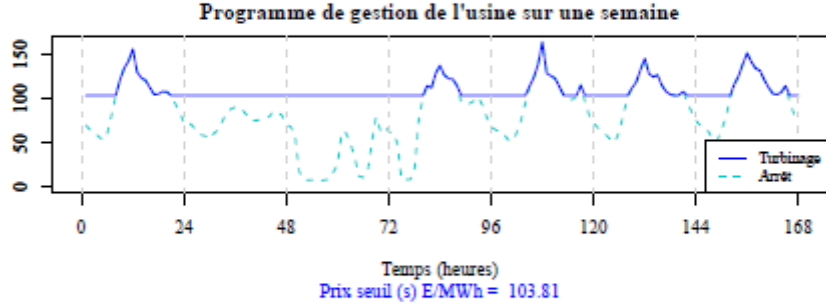# Results: illustration for one day of single forecast (1/3)

- Sep 5th 2008:
  Predicted inflow to
  the Durance
  reservoir for the
  next 7 days

- Energy prices
  for the week

- Turbine capacity =
  3 * mean daily flow

- Reservoir
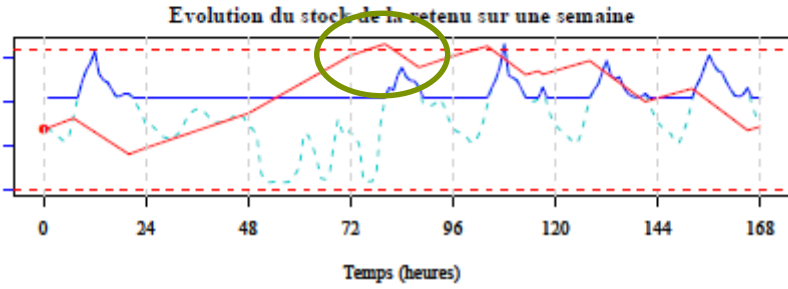 capacity = 4 days
  of mean daily flow

Q (m³/s)

2008−09−05 − Débit moyen journalier prévu − RECTIFICATION = 0

Horizon de prévision (jours)
Débit moyen prévu sur 7 jours = 81.54 m3/s

P R I C E S

Programme de gestion de l'usine sur une semaine

Turbinage
Arrêt

Indicator:
turbine
on/off

Temps (heures)
Prix seuil (s) E/MWh = 103.81

S T O R A G E

Evolution du stock de la retenu sur une semaine

Smax

Smin = 0

Temps (heures)
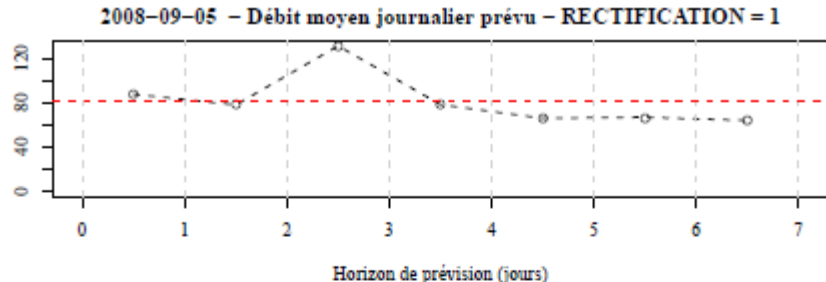
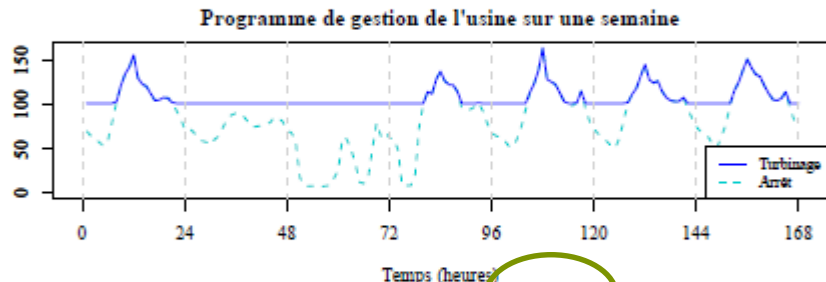# Results: illustration for one day of single forecast (2/3)

- Sep 5th 2008:
  Predicted inflow to the Durance reservoir for the next 7 days

- Energy prices for the week

- Turbine capacity = 3 * mean daily flow

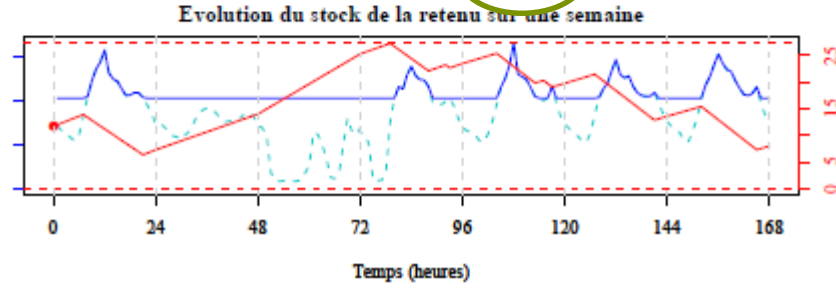- Reservoir capacity = 4 days of mean daily flow

Q (m³/s)

2008-09-05 – Débit moyen journalier prévu – RECTIFICATION = 1

Horizon de prévision (jours)
Débit moyen prévu sur 7 jours = 81.54 m3/s

P R I C E S

Programme de gestion de l'usine sur une semaine

Turbinage
Arrêt

Temps (heures)
Prix seuil (s) E/MWh = 101.99

S T O R A G E

Evolution du stock de la retenu sur une semaine

Smax

OK!!

Smin = 0

Temps (heures)
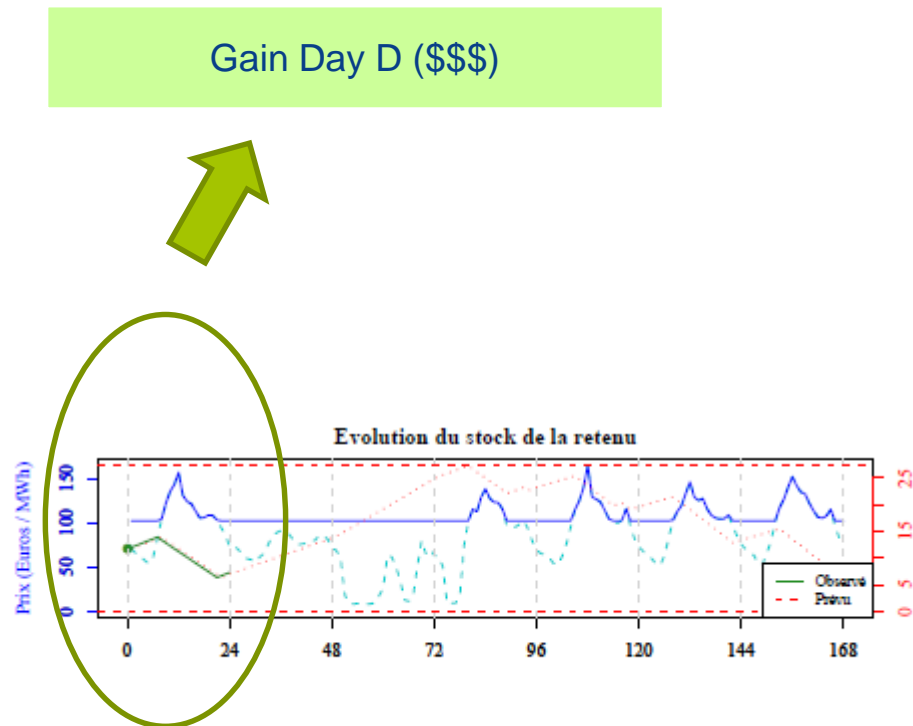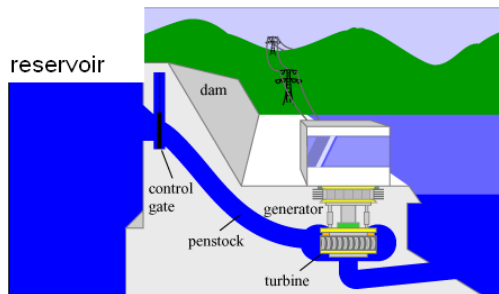
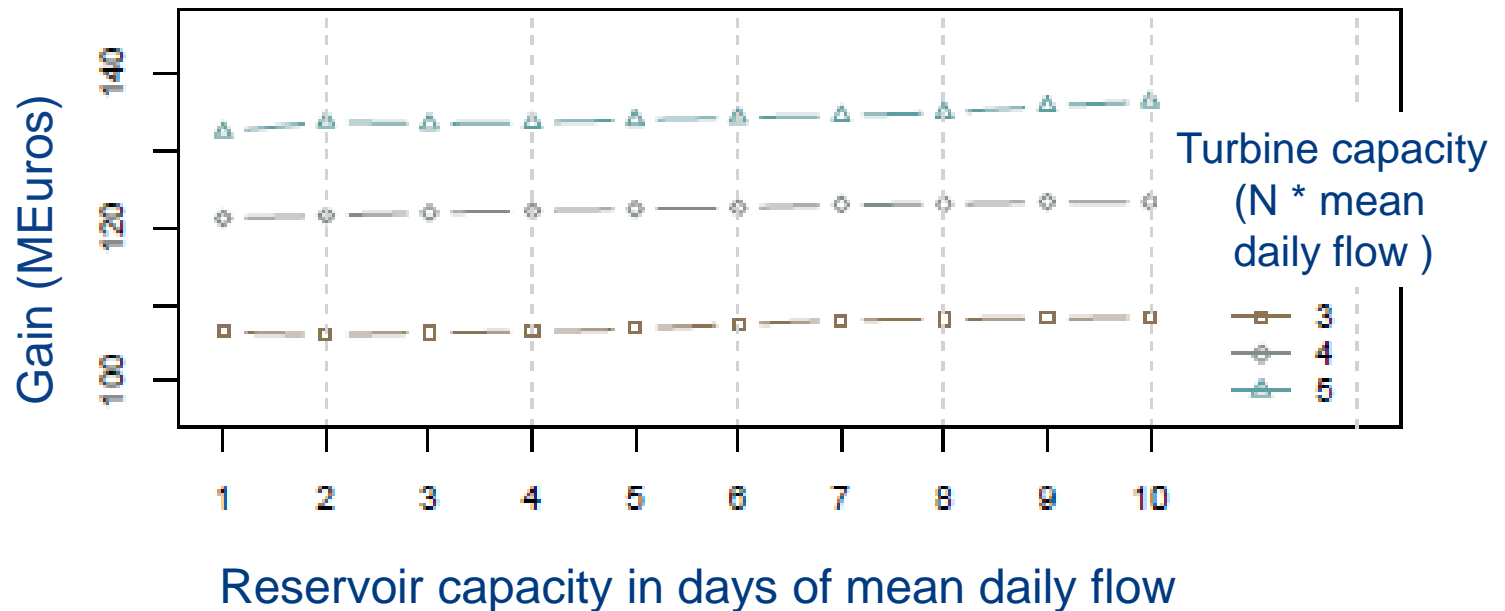# Results: illustration for one day of single forecast (3/3)

- Sep 5th 2008:
  Predicted inflow to the Durance reservoir for the next 7 days

- Energy prices for the week

- Turbine capacity = 3 * mean daily flow

- Reservoir capacity = 4 days of mean daily flow

- Run the observed flows through the management rule (24h)

Gain Day D ($$$)

Evolution du stock de la retenu

Results: sensitivity to system's characteristics

Forecasts: Ensemble forecasts (2005 – 2008)

Turbine capacity
(N * mean
daily flow)

3
4
5

Gain (MEuros)

Reservoir capacity in days of mean daily flow

Results: over a 4-year period

- Different types of forecasts:

— Observed flows		— Climatology (Q)	
— Ensemble mean		— Deterministic forecast	
— Ensemble forecast (all members)			

Turbine capacity (4* mean daily flow)

Gain (MEuros)

Reservoir capacity in days of mean daily flow
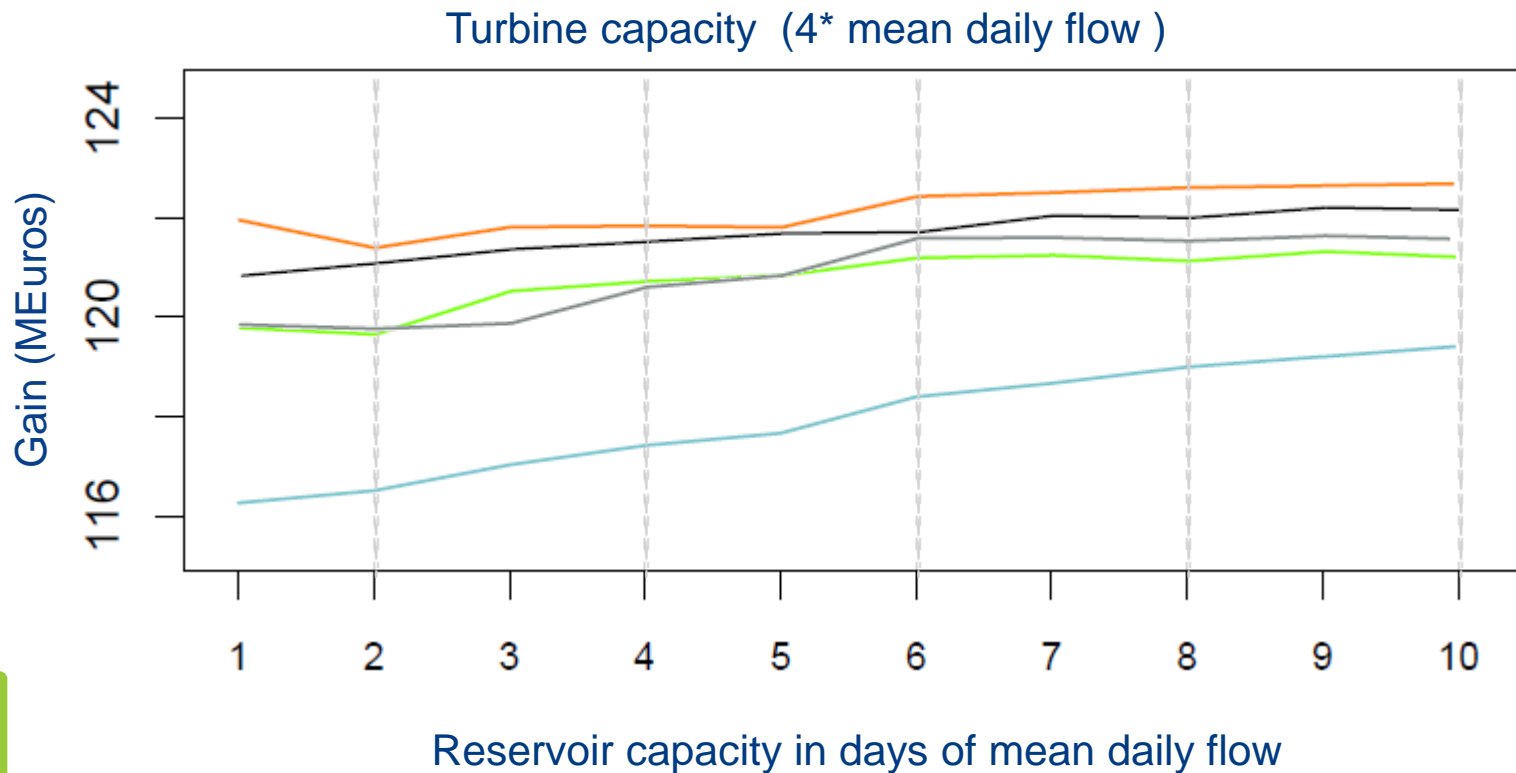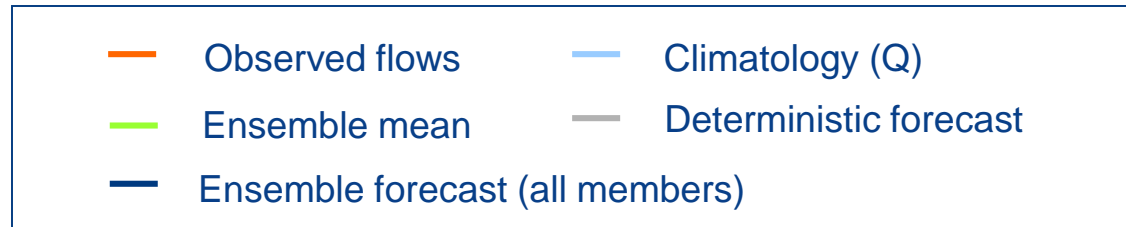
The value of hydrological ensemble predictions for reservoir inflow management

- Summary
    - An adaptable tool: heuristic algorithm connected with simulation model for reservoir rules under constraints
        - Different inflow scenarios
        - Different characteristics of reservoir & power system

    - The relative economic gains of using hydrometeorological ensemble forecasts comparatively to no forecasts at all (i.e., only climatological information) can potentially result in an average gain of 5% (over hundreds of M€).

    - Further studies
        - Improve the use of the probabilistic information from ensembles,
        - Impact of post-processing on energy production (quality ⇔ usefulness)

Thank you!

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See also