A seasonal low-flow forecasting and water management system to support reservoir management

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HEPEX Seasonal Forecasting Workshop

www.irstea.fr

The Arzal dam

Arzal reservoir

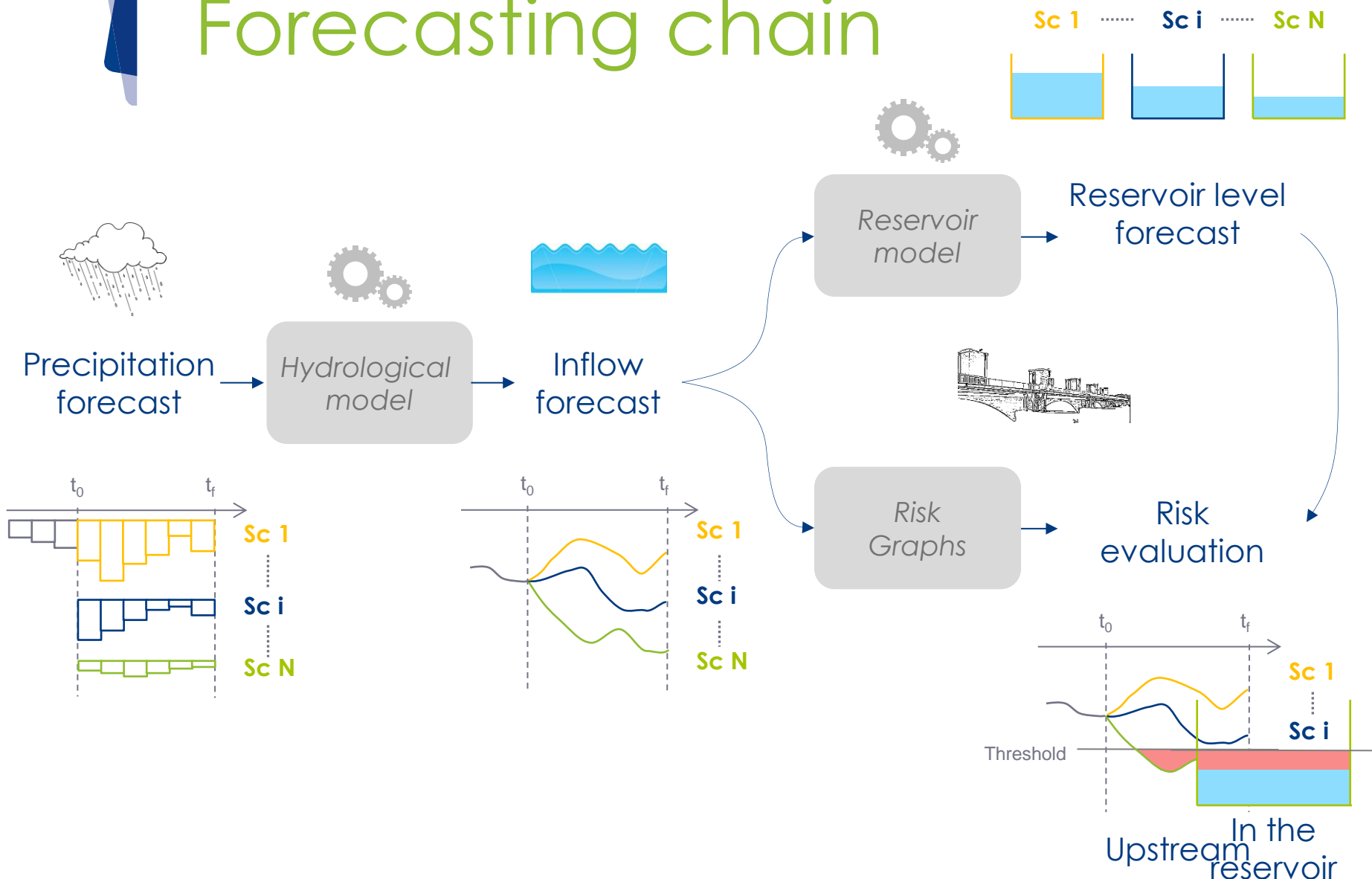Reservoir of 50 Mm3

Upstream: 10,000 km² catchment

Uses today
- Flood prevention
- Drinking water
- Boating
- Fish migration
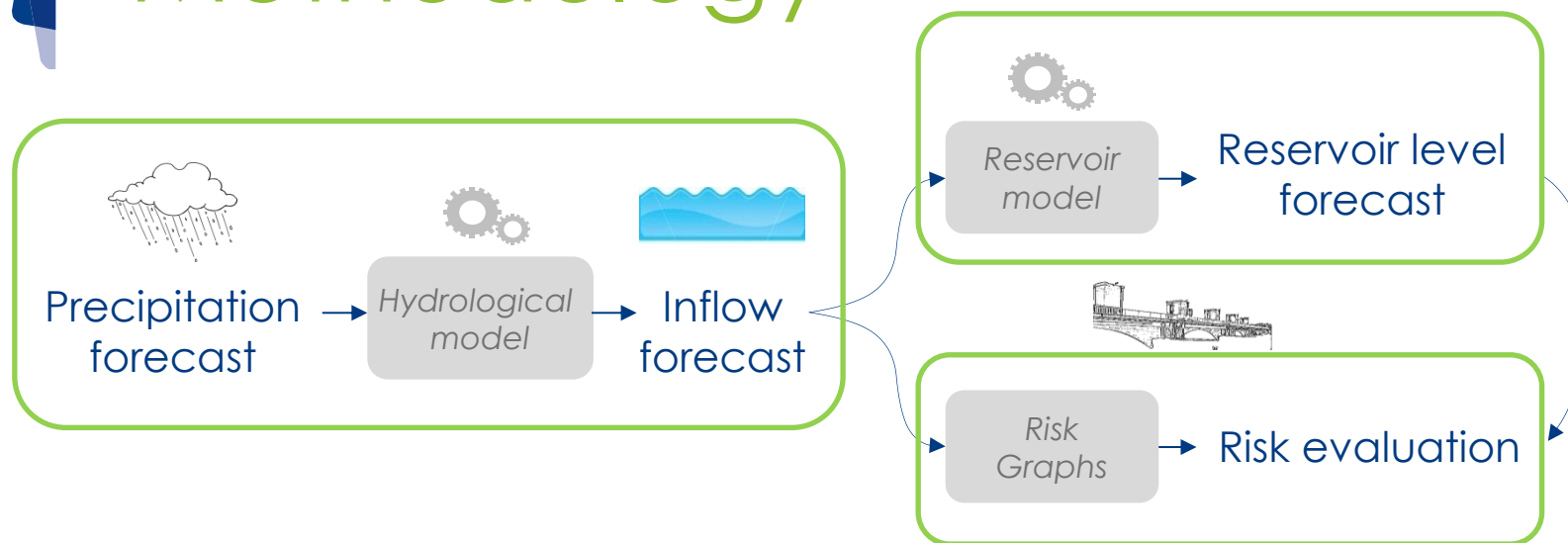
Possible conflicts in summer ⇨ Anticipate water quantity issues

Forecasting chain

Sc 1 ········· Sc i ········· Sc N

Precipitation forecast → *Hydrological model* → Inflow forecast

Reservoir model → Reservoir level forecast

Risk Graphs → Risk evaluation

t_0 t_f Sc 1 Sc i Sc N

t_0 t_f Sc 1 Sc i Sc N

t_0 t_f Sc 1 Sc i

Threshold

Upstream In the reservoir

Methodology

1. Forecast inflows at the seasonal lead time

2. Forecast low-flow variables at the seasonal lead time
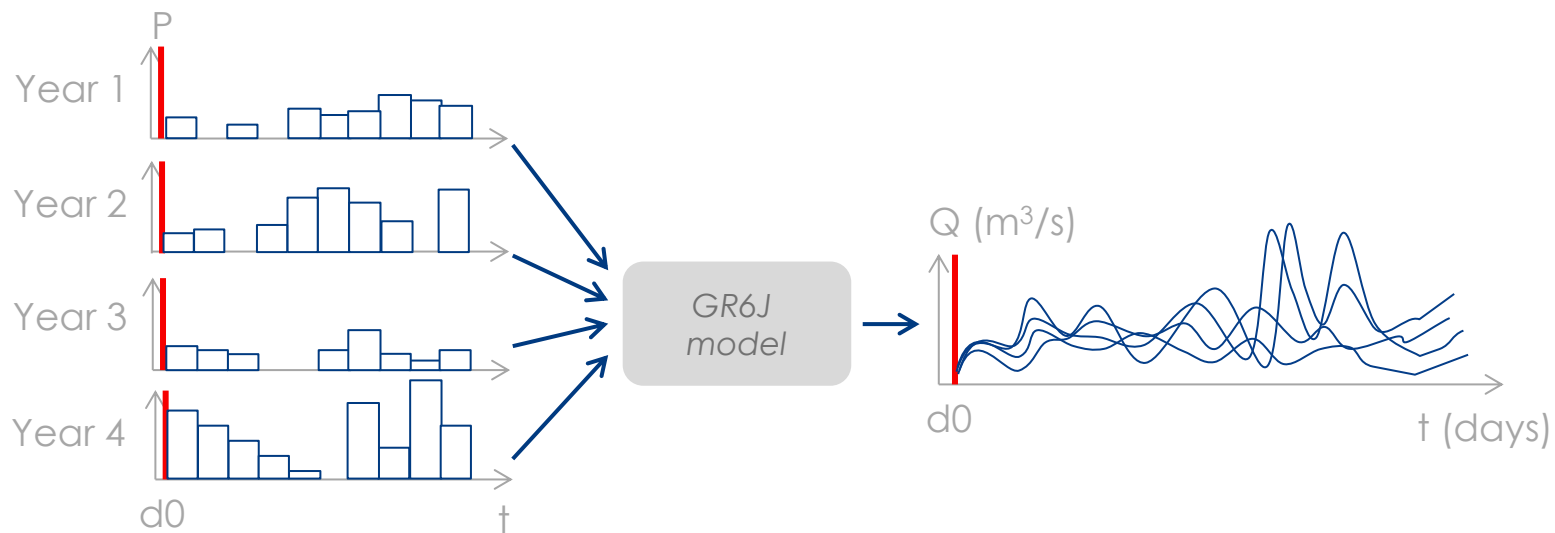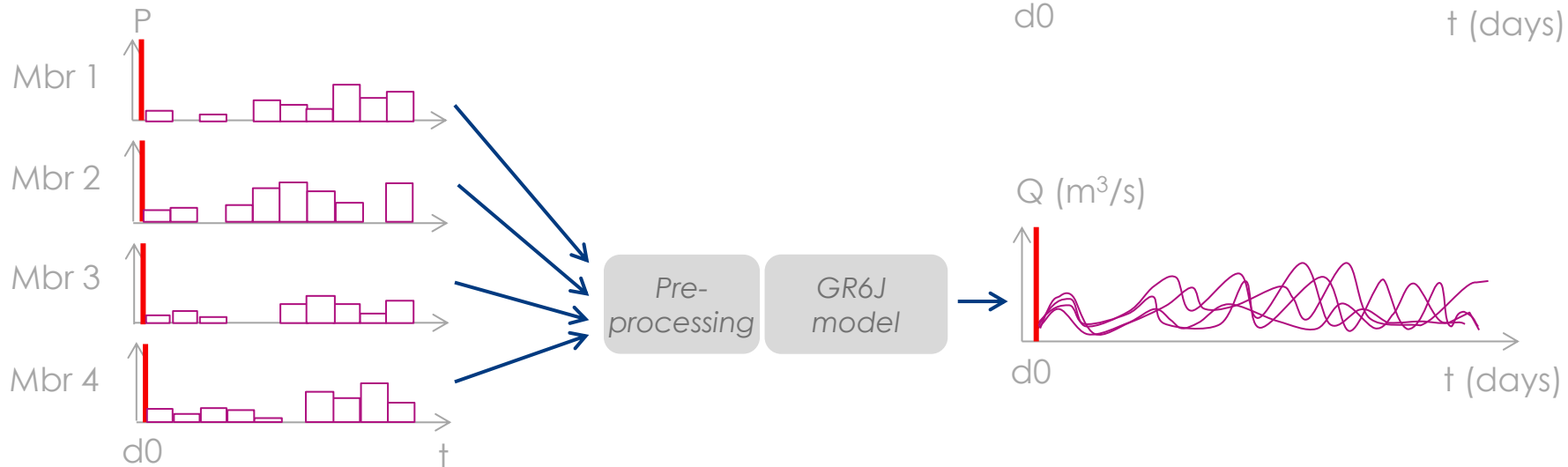
3. Model the Arzal reservoir

Methodology
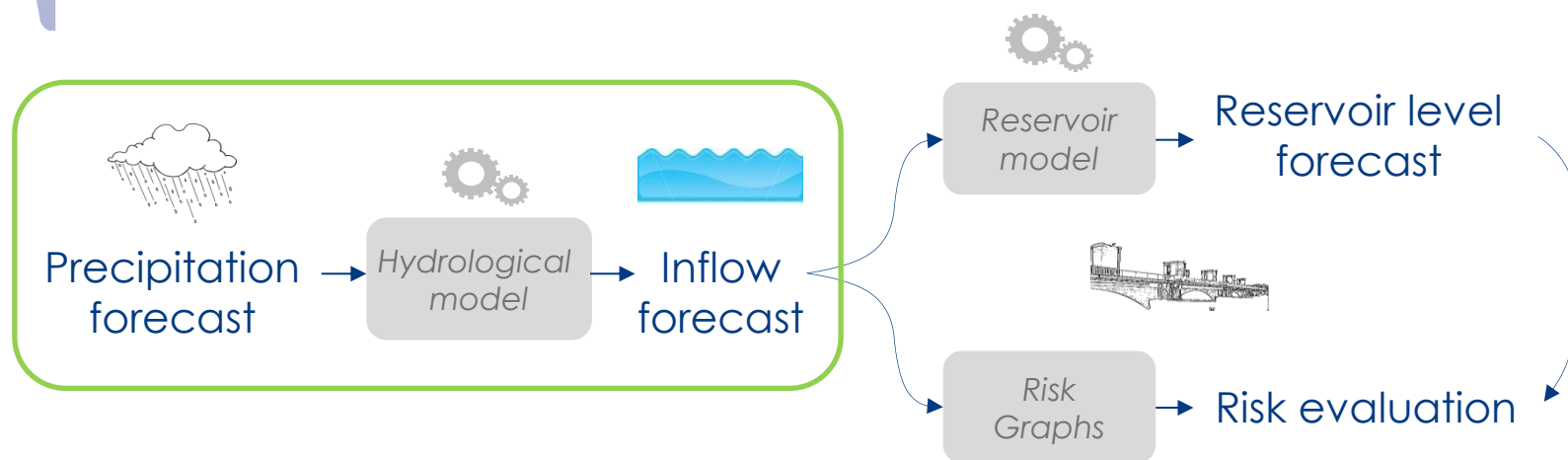
1. Forecast inflows at the seasonal lead time

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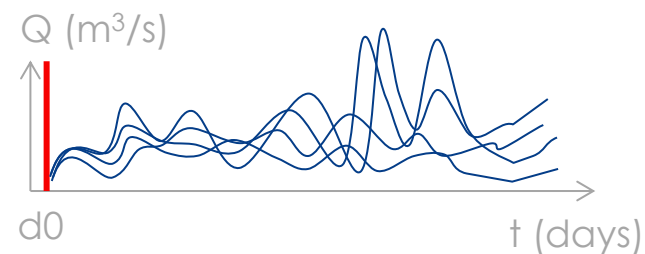
Forecast ensembles

Precipitation climatology

Year 1

Year 2

Year 3

Year 4

P

d0

t

GR6J model

Q (m³/s)

d0

t (days)

Forecast ensembles

Seasonal forecasts
from ECMWF

Forecast ensembles

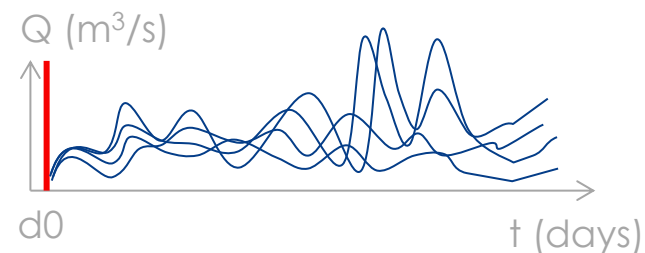**All Observations**

Precipitation climatology
+ Hydro model

Q (m³/s)

d0
t (days)

Seasonal precipitation forecasts
+ Hydro model

Q (m³/s)

d0
t (days)
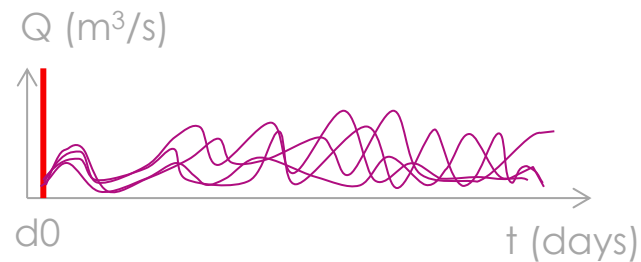
Forecast ensembles

Selection of historic information based on SPI3 →

Q (m^3/s)

d0 t (days)

Seasonal precipitation forecasts
+ Hydro model

Q (m^3/s)
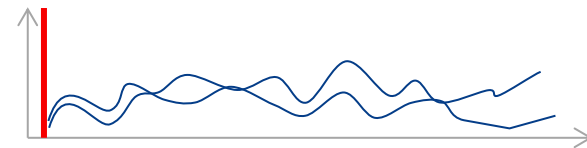
d0 t (days)

Forecast ensembles

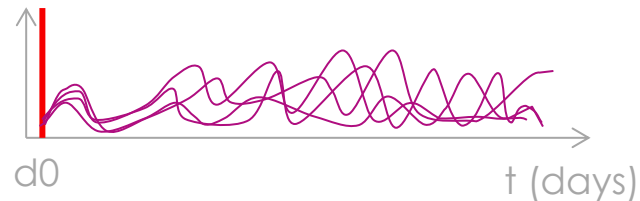Precipitation climatology
+ Hydro model

Q (m³/s)
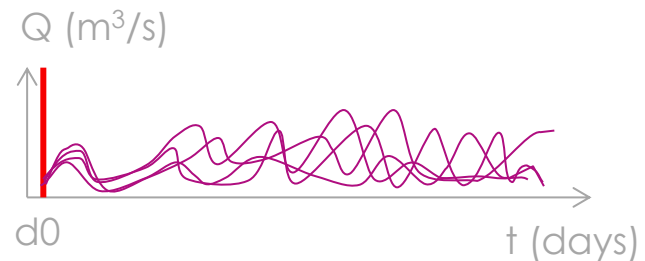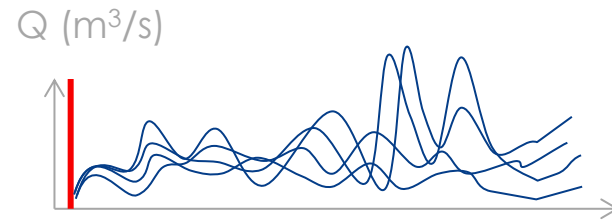
Available precipitations

Selected Precipitation climatology
+ Hydro model

15 members

Seasonal precipitation forecasts
+ Hydro model

15 members

d0   t (days)

Evaluation

- Streamflow records at the Vilaine : too short for robust comparison

- Use of other catchments for validation

  - 16 French catchments

  - From the PREMHYCE project database   *Nicolle et al. 2014*

- Available data

  - Q observed   > 30 yrs   Banque HYDRO
  - P observed   1958 - 2011   SAFRAN reanalysis
  - P forecast   1981 - 2010   ECMWF forecasts

Evaluation

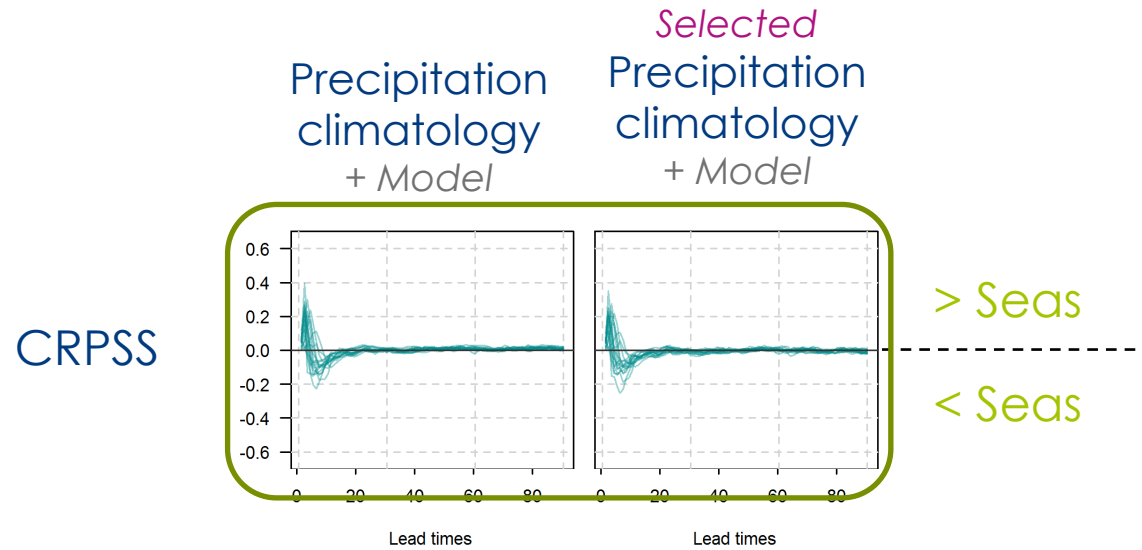| Quality	Criterion	Description
Overall performance	CRPS	Error in the cumulative distribution
Reliability	PIT	Forecast probability vs. Observed probability
Sharpness	IQR 90%	« Width » of the ensemble

➡ Skill score in regards to a reference

If   Skill > 0 , then   Syst > Ref
If   Skill = 0 , then   Syst ~ Ref
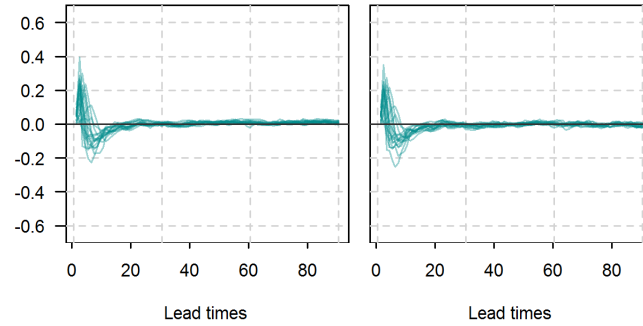If   Skill < 0 , then   Syst < Ref

$$Skill = 1 - \frac{Score\ (syst)}{Score\ (ref)}$$

Selected

Precipitation climatology + *Model*

Precipitation climatology + *Model*

CRPSS

> Seas

< Seas

Lead times

Lead times

ECMWF forecasts are the best ensemble overall
ClimP_SPI3 and ClimP equivalent at long lead times

Precipitation climatology *+ Model*

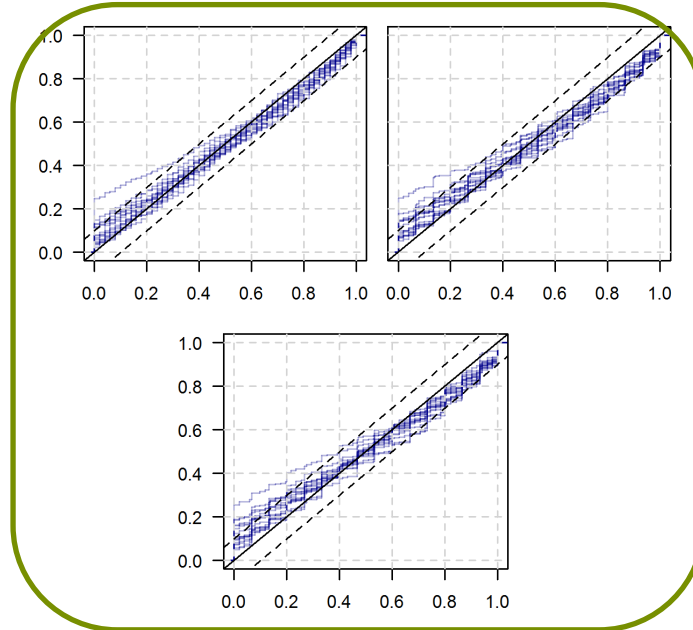*Selected* Precipitation climatology *+ Model*
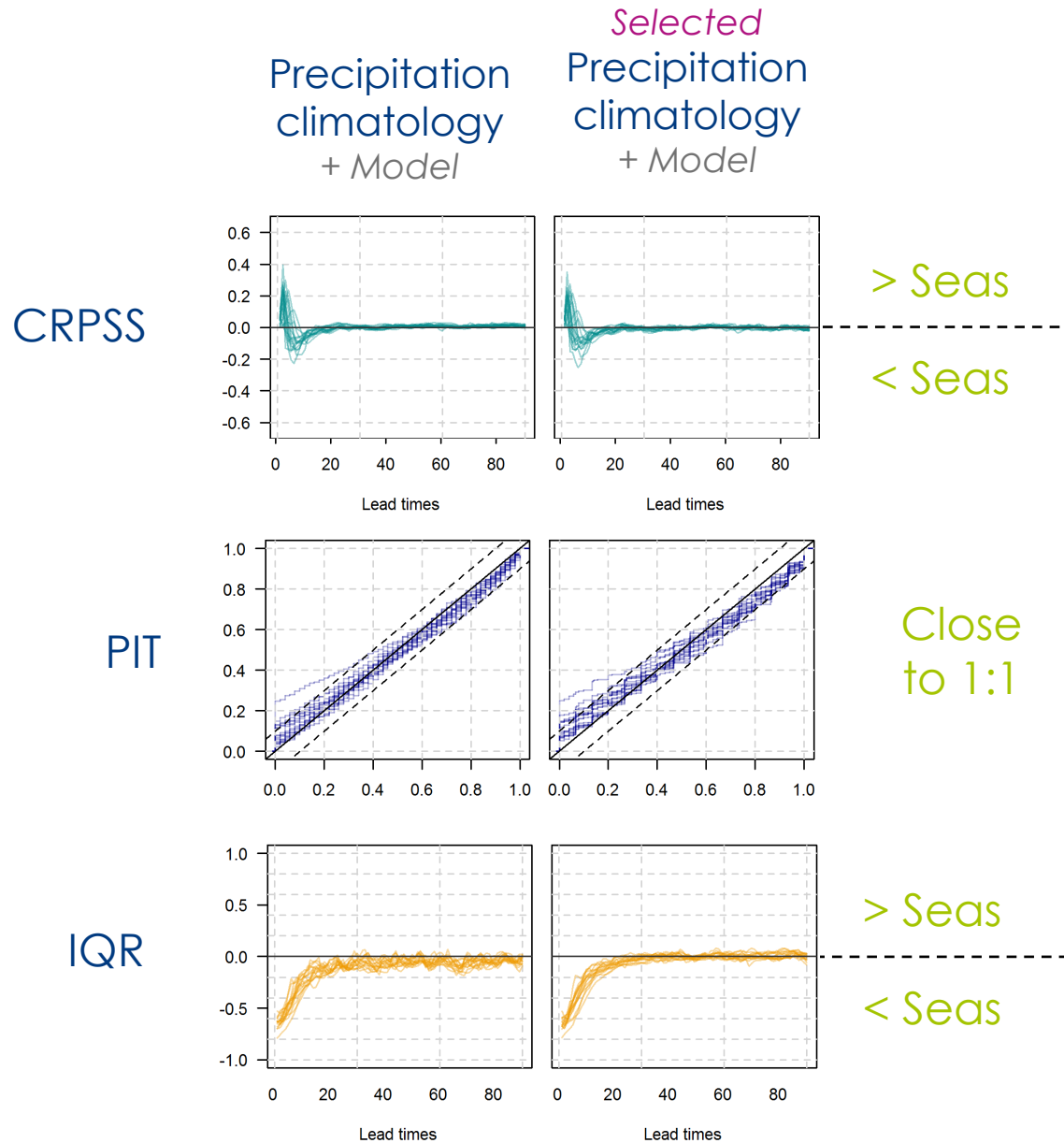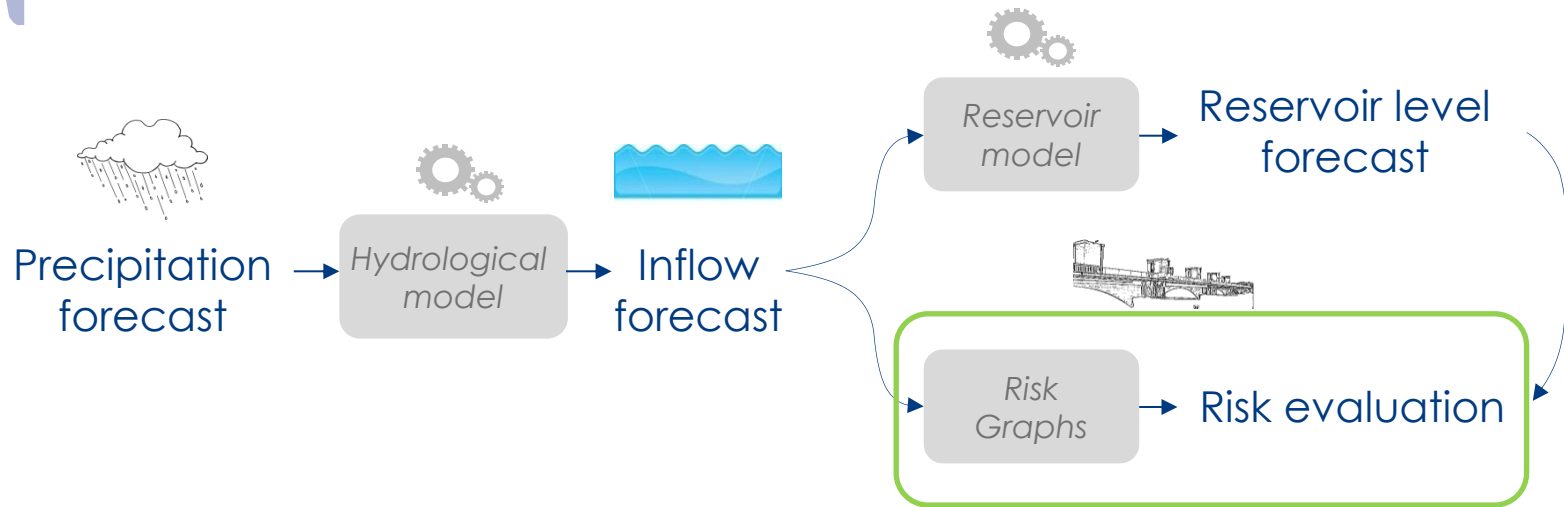
CRPSS

> Seas

< Seas

PIT

Close to 1:1

All reliable

Lead times

Lead times

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Ecmwf forecasts and selected
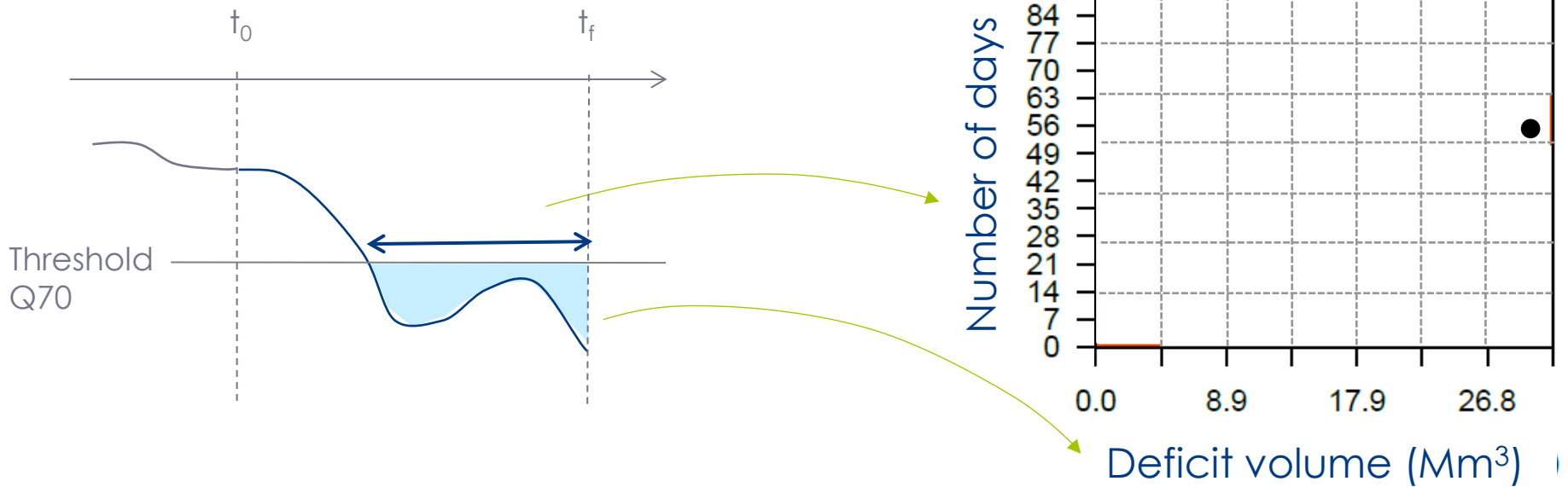ensembles are the sharpest ensembles

Methodology

1. Forecast inflows at the seasonal lead time

2. **Forecast low-flow variables at the seasonal lead time**
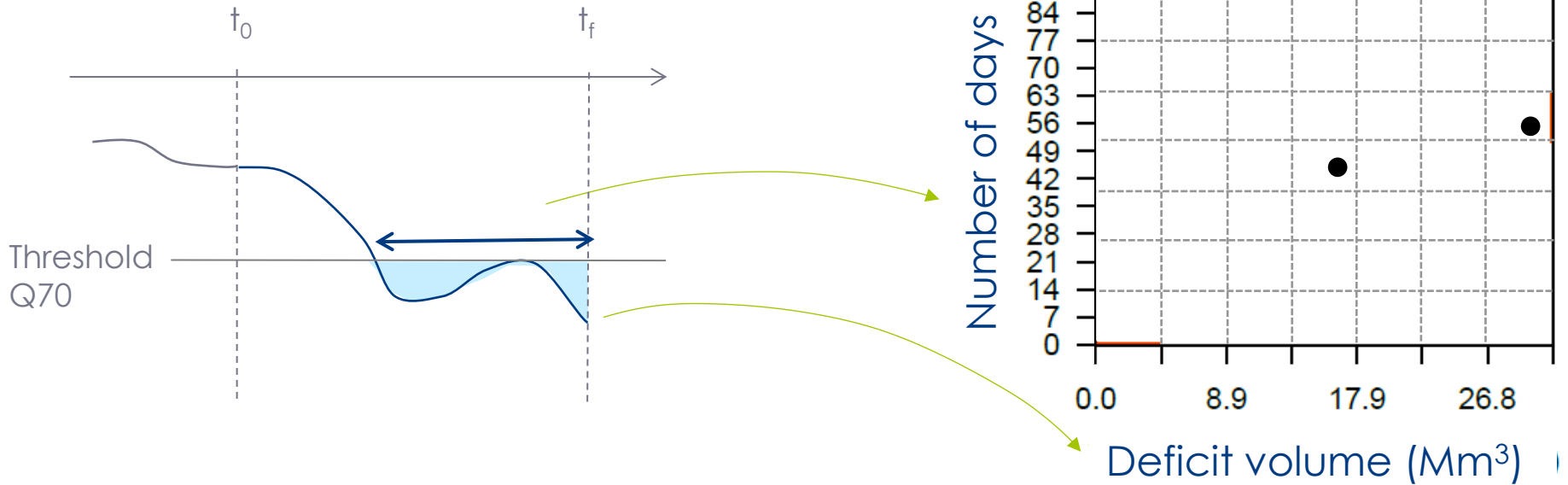
3. Model the Arzal reservoir
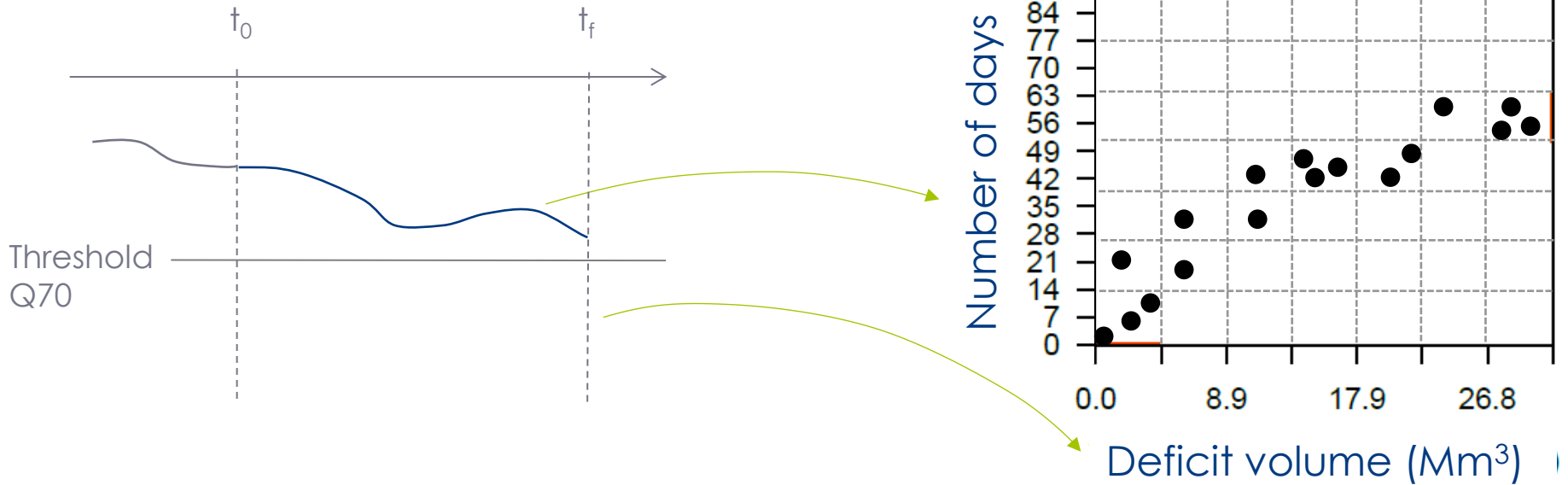
Risk graph

Building of graph

Threshold Q70

t_0 t_f

Number of days

84
77
70
63
56
49
42
35
28
21
14
7
0

0.0   8.9   17.9   26.8

Deficit volume (Mm^3)

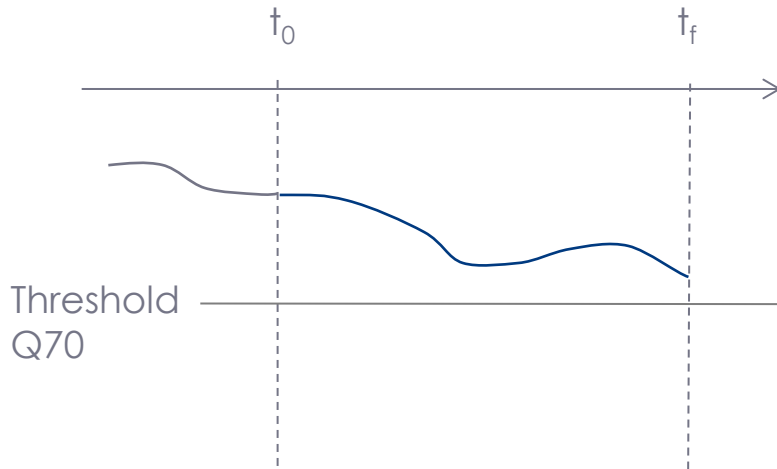# Risk graph

Building of graph

Risk graph

Building of graph

Threshold Q70

t_0 t_f

Number of days

84 77 70 63 56 49 42 35 28 21 14 7 0

0.0 8.9 17.9 26.8

Deficit volume (Mm^3)

Risk graph

Building of graph

Threshold Q70

t_0 t_f

Number of days: 84 77 70 63 56 49 42 35 28 21 14 7 0

Deficit volume (Mm^3): 0.0   8.9   17.9   26.8
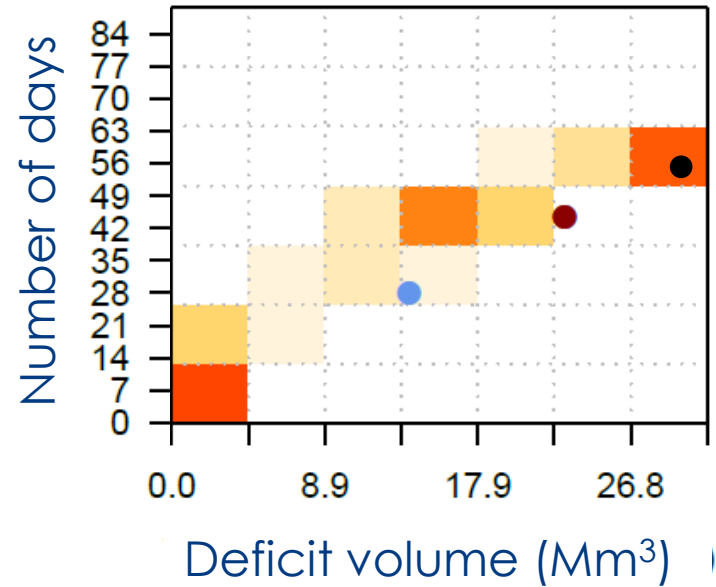
● observed   ● climatology   ● drought
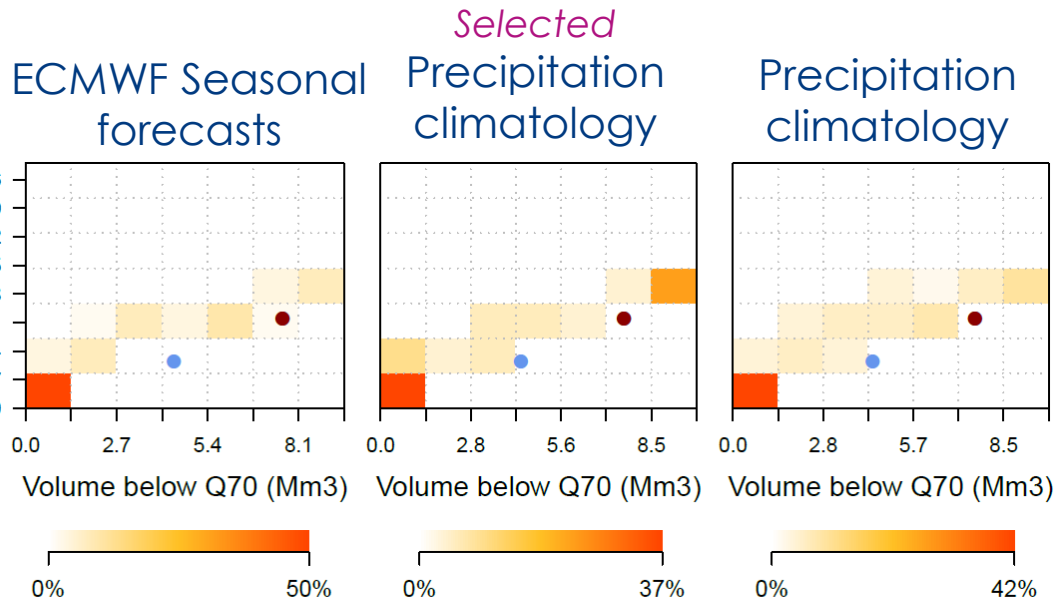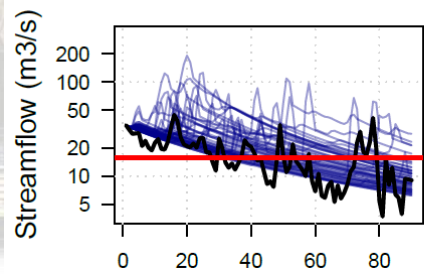
0%   23%

Risk graphs

Arzal reservoir

Forecast date : 1/5/2005   Q70 = 15 m³/s
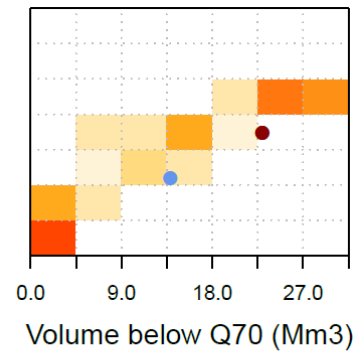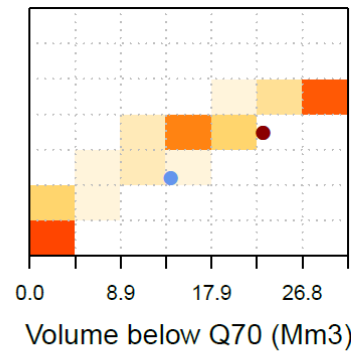
Risk graphs

Arzal reservoir

Forecast date : 1/5/2005   Q70 = 15 m³/s

Selected

ECMWF Seasonal forecasts | Precipitation climatology | Precipitation climatology
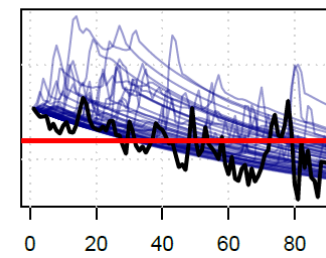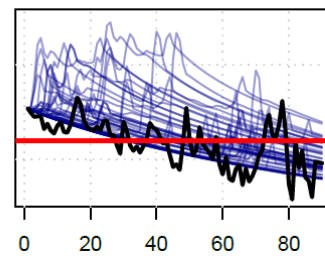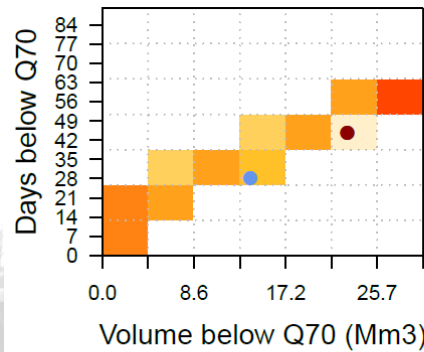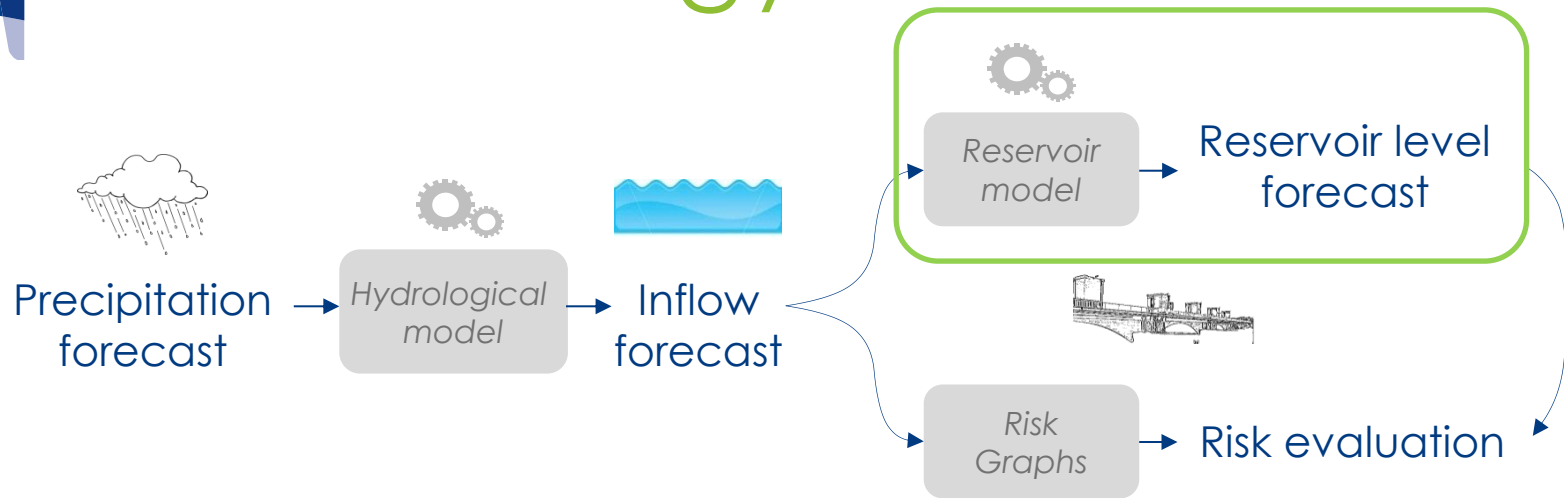
Risk graphs

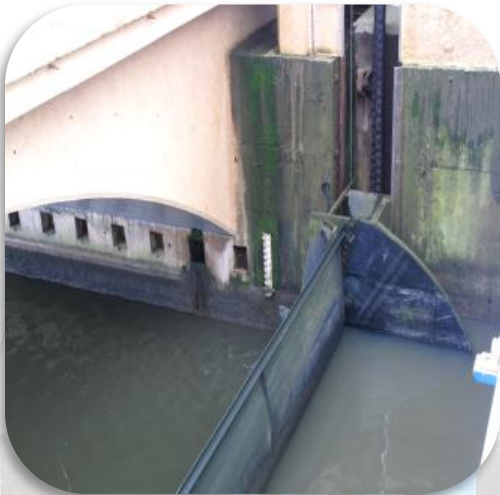Forecast date : 1/5/2005   Q70 = 15 m³/s

Methodology

1. Forecast inflows at the seasonal lead time

2. Forecast low-flow variables at the seasonal lead time

3. **Model the Arzal reservoir**

The Arzal dam

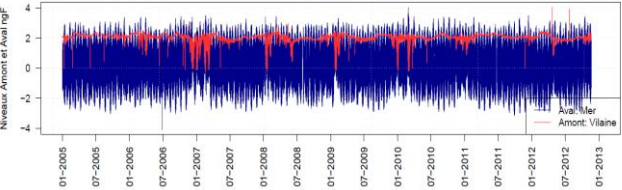

Shutters and Sluice gates

Lock
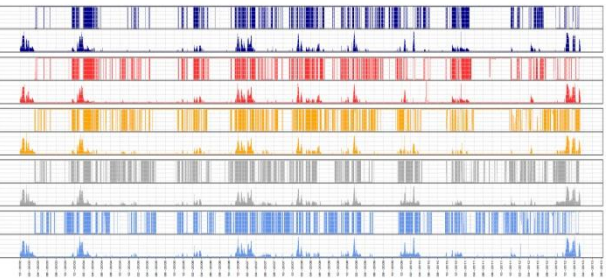

Siphon

Fish pass and Fish scale

irstea

The Arzal dam

Measured levels upstream and downstream (ngF)
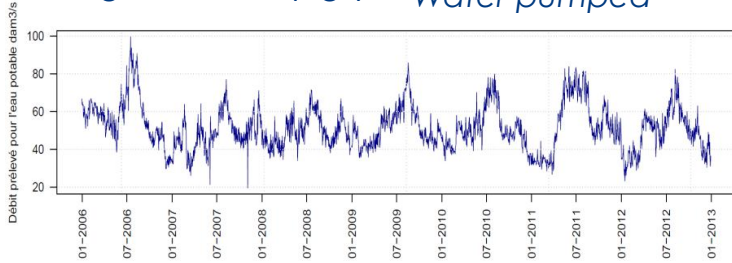

Shutters and sluice gates levels (ngF)
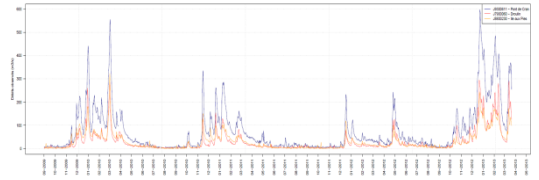

View of the Arzal dam (source: Google Maps)

Water pumped

Flow through the siphons (m3/s)

Observed streamflow upstream (m3/s)
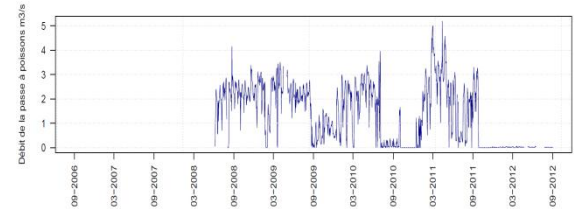
Streamflow through the fish pass (m3/s)

Reservoir balance

Vilaine river

Ocean

Q pumped

Q inflow

Q fish pass
Q sluice gates
Q shutters
Q lock
Q siphons

P   ET
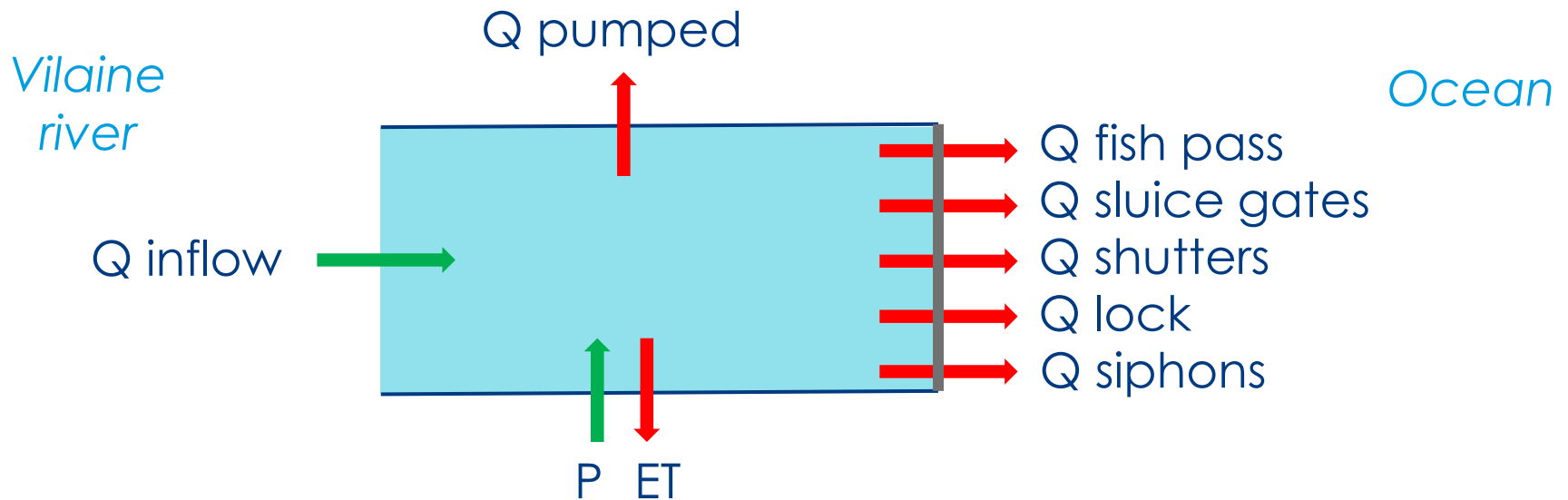
$$V[\,t\,] = V[\,t\text{-}1\,] + \Delta V[\,t\,]$$

$$\Delta V[\,t\,] = \mathbf{+}\ V_{in}[\,t\,]\ \mathbf{-}\ V_{out}[\,t\,]$$

Reservoir balance

Q pumped

Vilaine river

Ocean

Q fish pass

Q sluice gates

Q inflow

Q shutters

Q lock

Q siphons

P ET
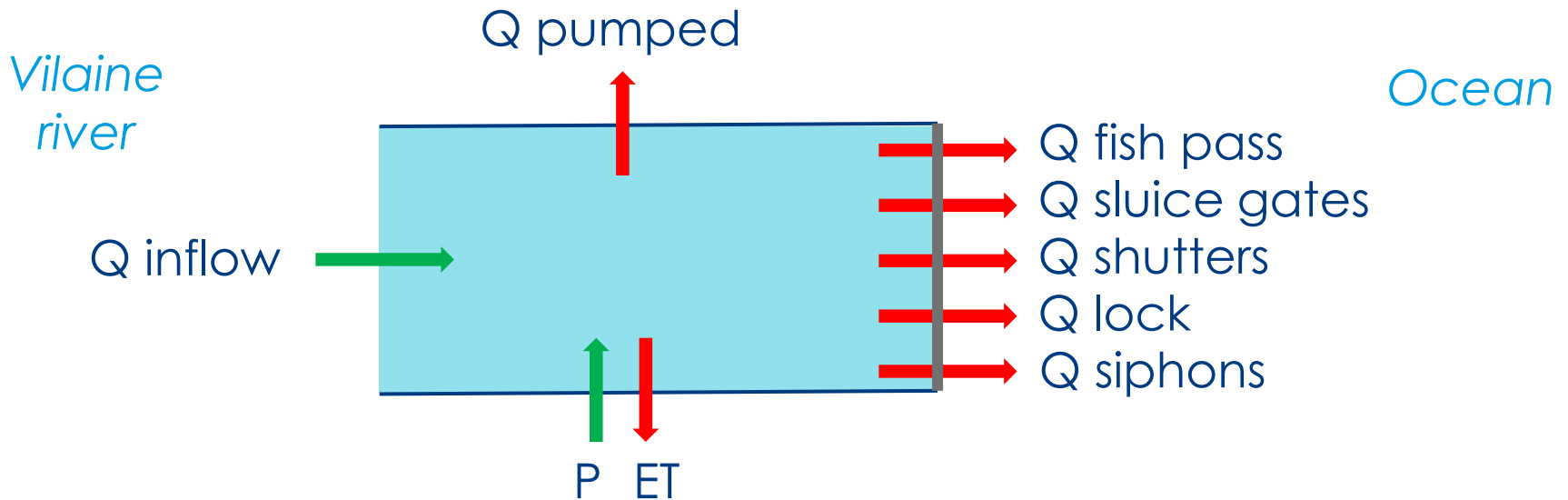
$$V[\,t\,] = V[\,t\text{-}1\,] + \Delta V[\,t\,]$$

$$\Delta V[\,t\,] = \mathbf{+}\ V\ \text{inflows}[\,t\text{-}1\,]\ \mathbf{+}\ V\ P[\,t\,]\ \mathbf{-}\ V\ \text{ETP}[\,t\,]$$

$$\mathbf{-}\ V\ \text{sluice gates}[\,t\,]\ \mathbf{-}\ V\ \text{shutters}[\,t\,]\ \mathbf{-}\ V\ \text{siphons}[\,t\,]$$

$$\mathbf{-}\ V\ \text{lock}[\,t\,]\ \mathbf{-}\ V\ \text{withdrawals}[\,t\,]\ \mathbf{-}\ V\ \text{fish pass}[\,t\,]$$

Reservoir balance
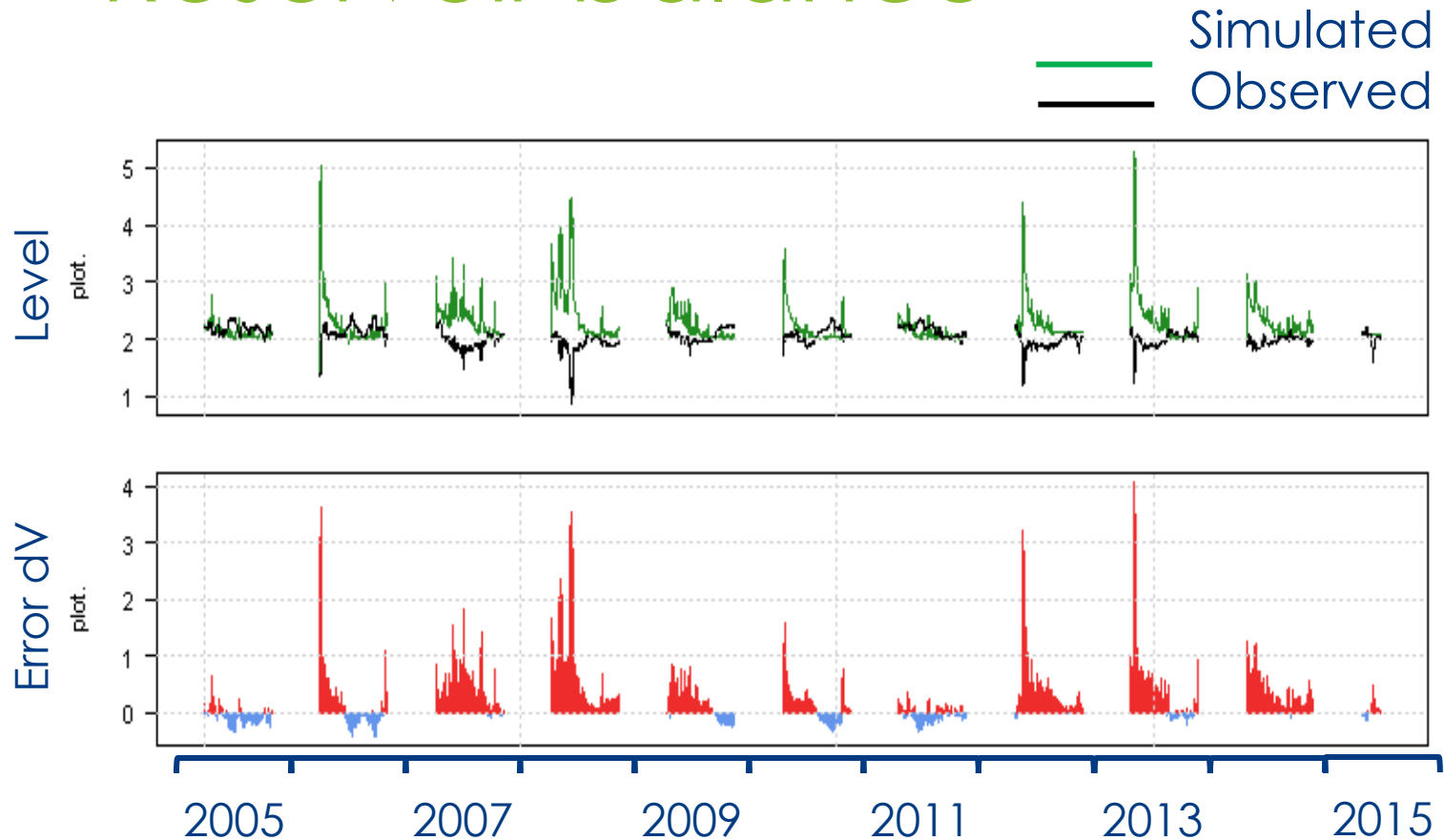
→ Investigation needed

Conclusions

- Comparison of several pre-processing for ECMWF seasonal precipitation forecasts

- Comparison of several inflow forecasts

- Building of risk visualization graphs

- Simulations based on simple reservoir balance

Perspectives

- Correct terms in reservoir balance

- Test reservoir model for extreme scenarios

- Test post-processing of streamflow forecasts

Thank you !

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