Seasonal forecasting of water resources

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Mediterranean water scarcity

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- Water scarcity is a recurrent problem in the Mediterranean

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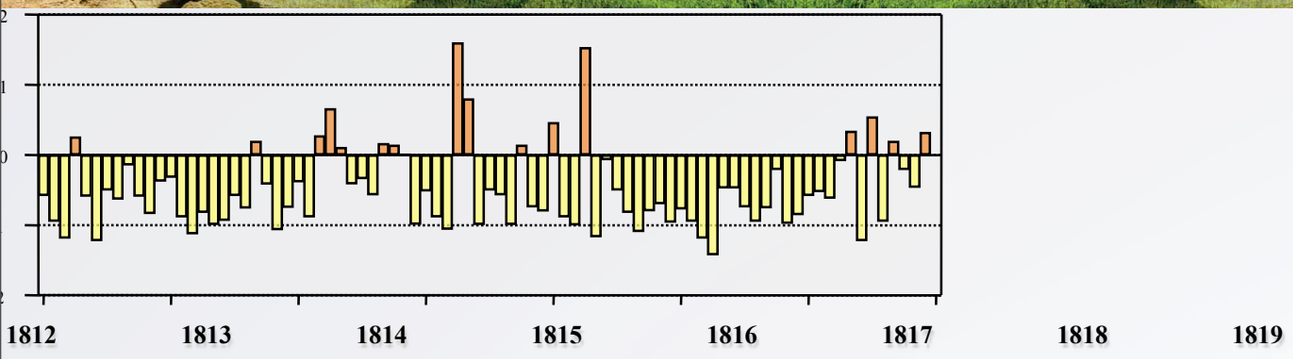

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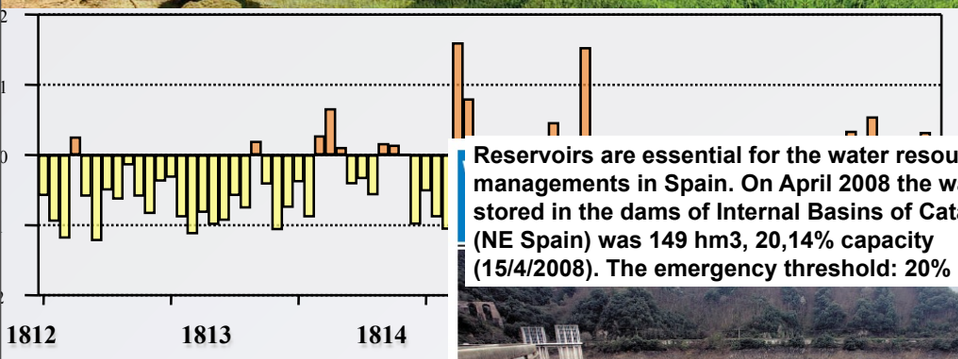

Reservoirs are essential for the water resources managements in Spain. On April 2008 the water stored in the dams of Internal Basins of Catalonia (NE Spain) was 149 hm3, 20,14% capacity (15/4/2008). The emergency threshold: 20%

Tocando fondo. El nivel de las aguas del pantano de Susqueda sigue muy bajo a pesar de las últimas lluvias caídas en la cuenca del Ter

Emergencia nacional

● El Govern califica en términos dramáticos la sequía y trata de buscar un pacto con CiU que ahuyente la guerra del agua

RAMON SUÑÉ
Barcelona

Cataluña vive un estado de "emergencia nacional" por culpa de la sequía y es tal la gravedad de la situación que está más que justificado un acuerdo político al más alto nivel, entre el presidente de la Generalitat y el líder de la oposición. El conseller de Medi Ambient i Habitatge, Francesc Baltasar, hizo ayer esta apelación, con tintes dramáticos y patrióticos, para afirmar que la dimensión del problema que afronta el país, con una serie amenaza de restricciones al consumo doméstico pendiendo sobre las cabezas de cinco millones habitantes del área metropolitana de Barcelona, "merecería" un encuen-

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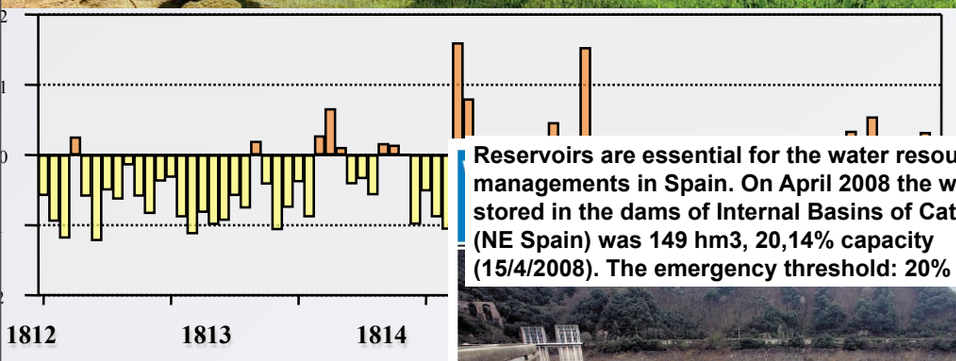

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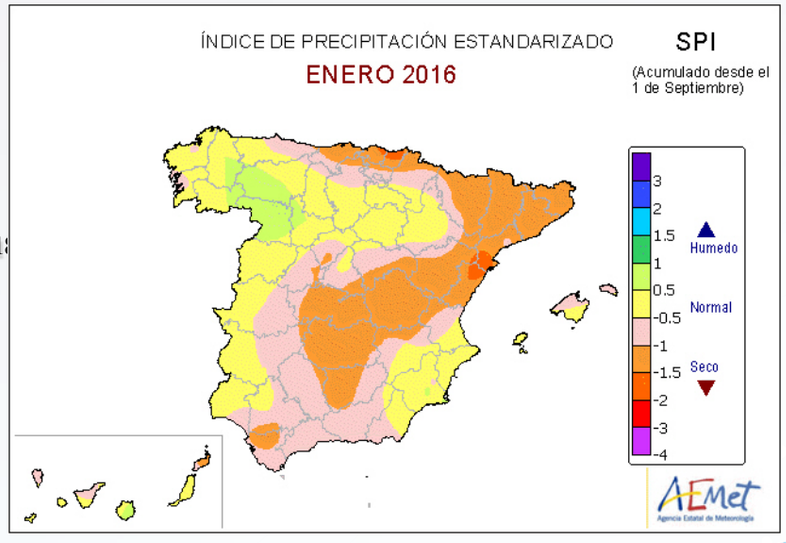

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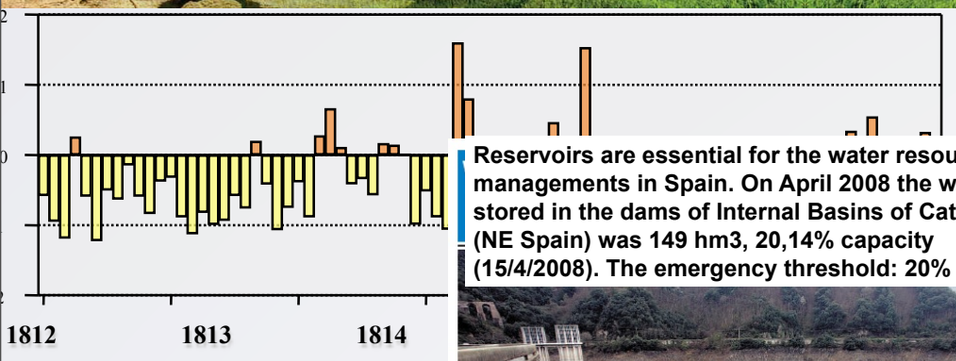

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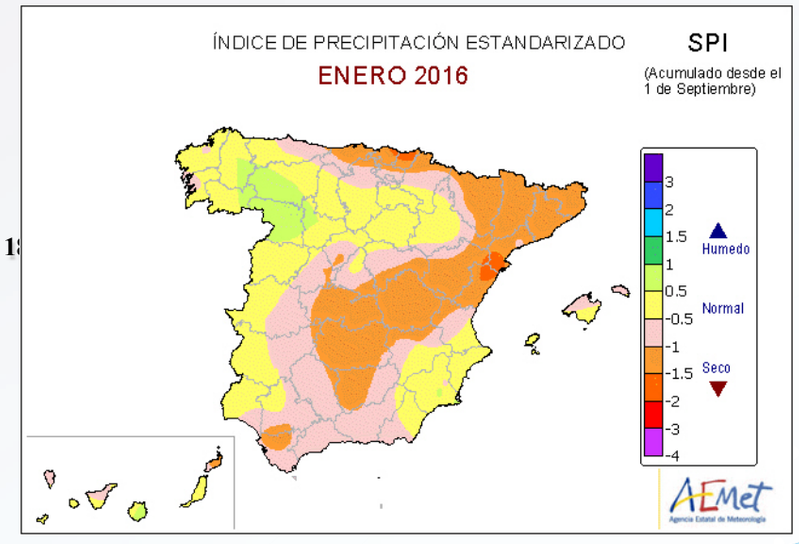

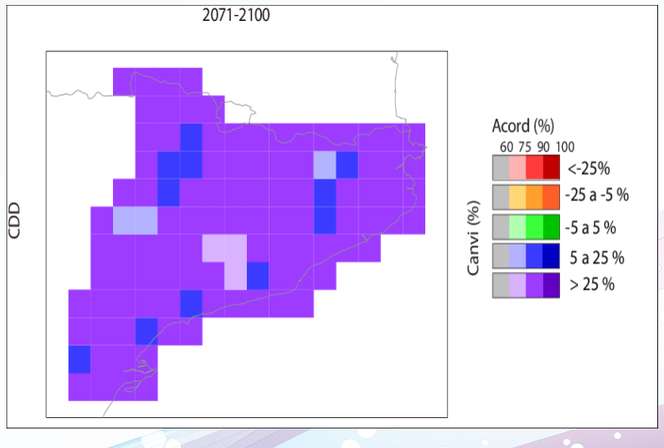

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- Water scarcity is a recurrent problem in the Mediterranean

- Linked to the relationship between:

Water supplies ⟷ Droughts ⟷ Water demands

Mediterranean water scarcity

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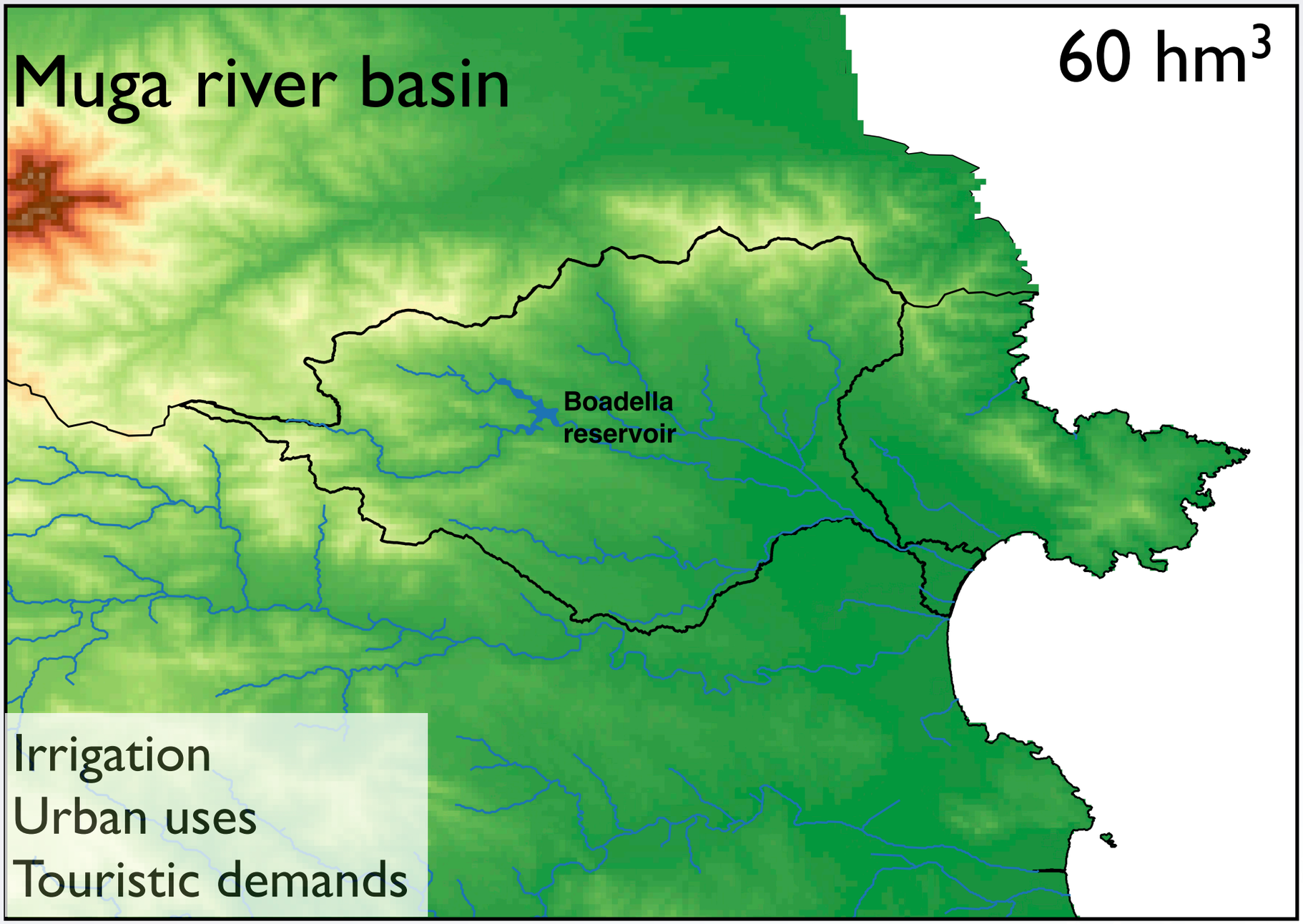
In this context foretelling the behaviour of dam **supplies** with months **in advance** can be used to optimize water management

- Linked to the relationship betv

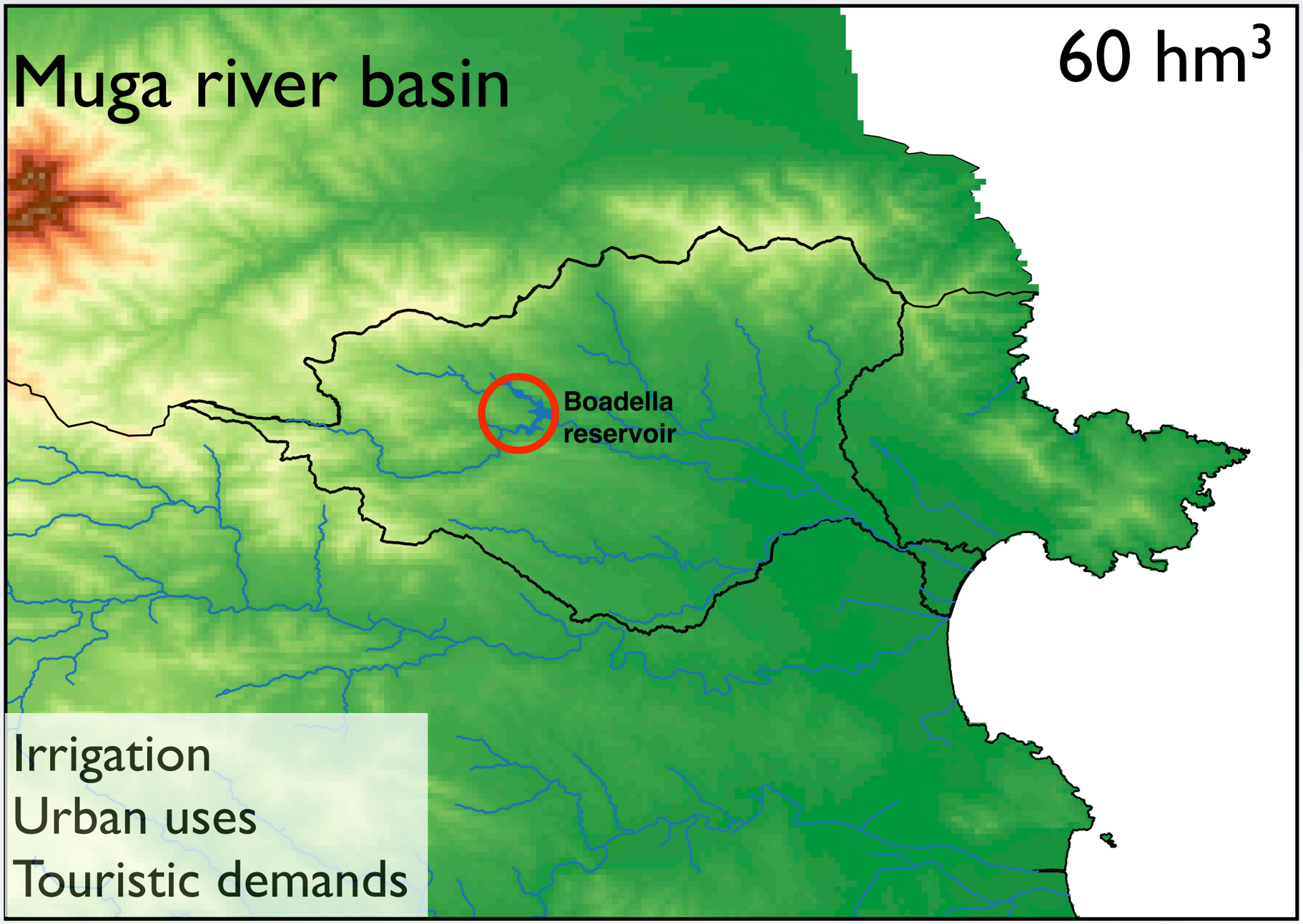
Water supplies

Boadella reservoir



Case study description | MLR construction | Predictability

Boadella reservoir



Case study description | MLR construction | Predictability

ECMWF System 4 data

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- Monthly **ECMWF System-4** precipitation and temperature **15-**member ensemble re-forecasts (0.75° x 0.75°) for the period **1981-2010**. Each initialization starts in the 1st day of each month encompassing a **7-month** time integration

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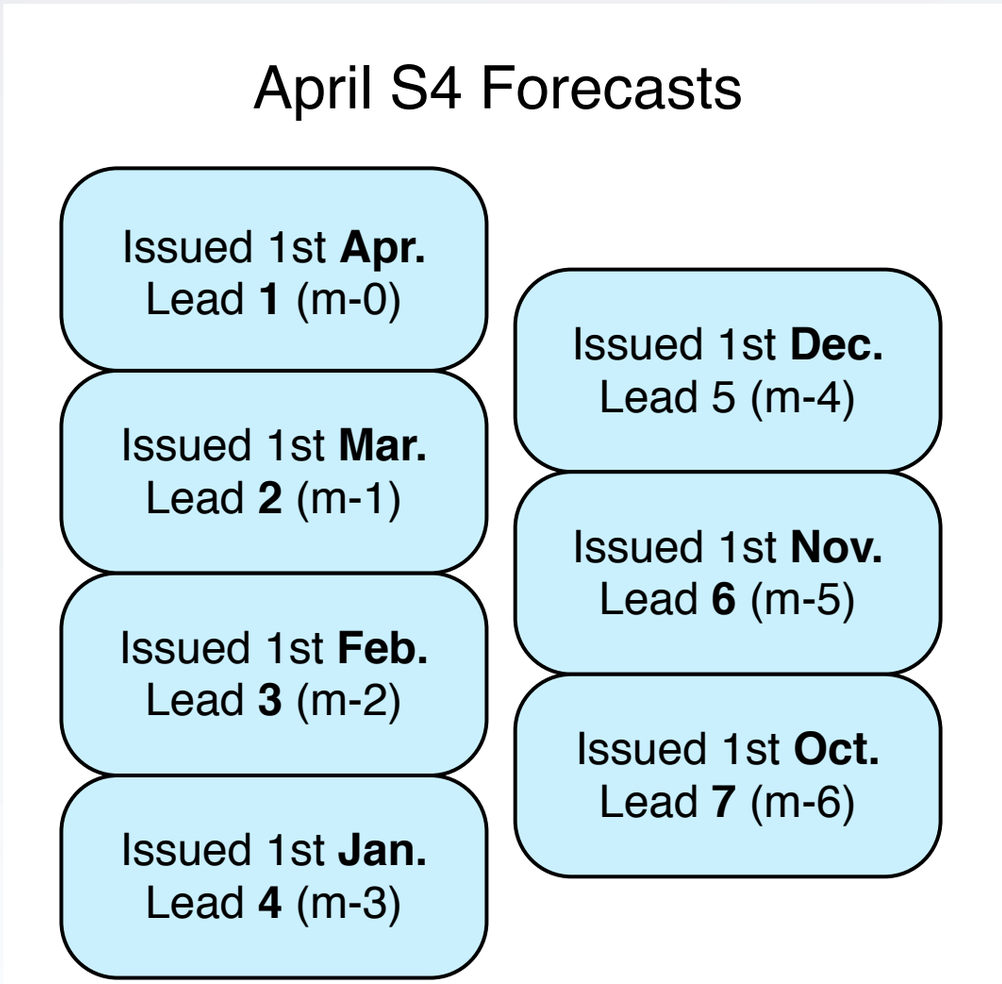
Interpretation example



E-OBS data

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- **E-OBS** daily **precipitation** and **temperature** high-resolution (0.25° x 0.25°) gridded dataset over the period **1981-2010**

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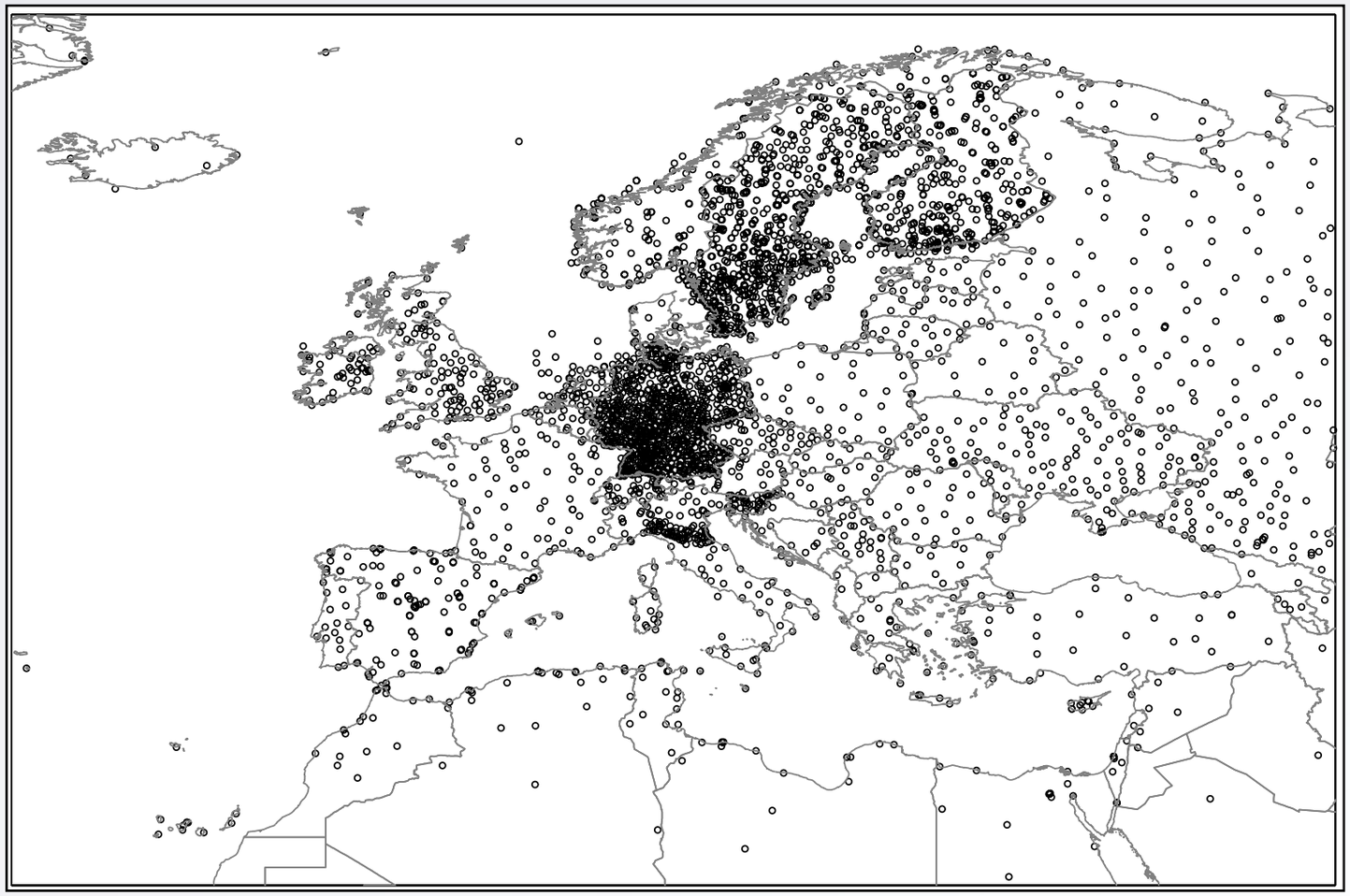


E-OBS v8.0 temperature station cover map for Europe.

Boadella data

Boadella data

- Monthly in-flow, out-flow and volume data **observed** at the **Boadella** reservoir for the period **1981-2010**

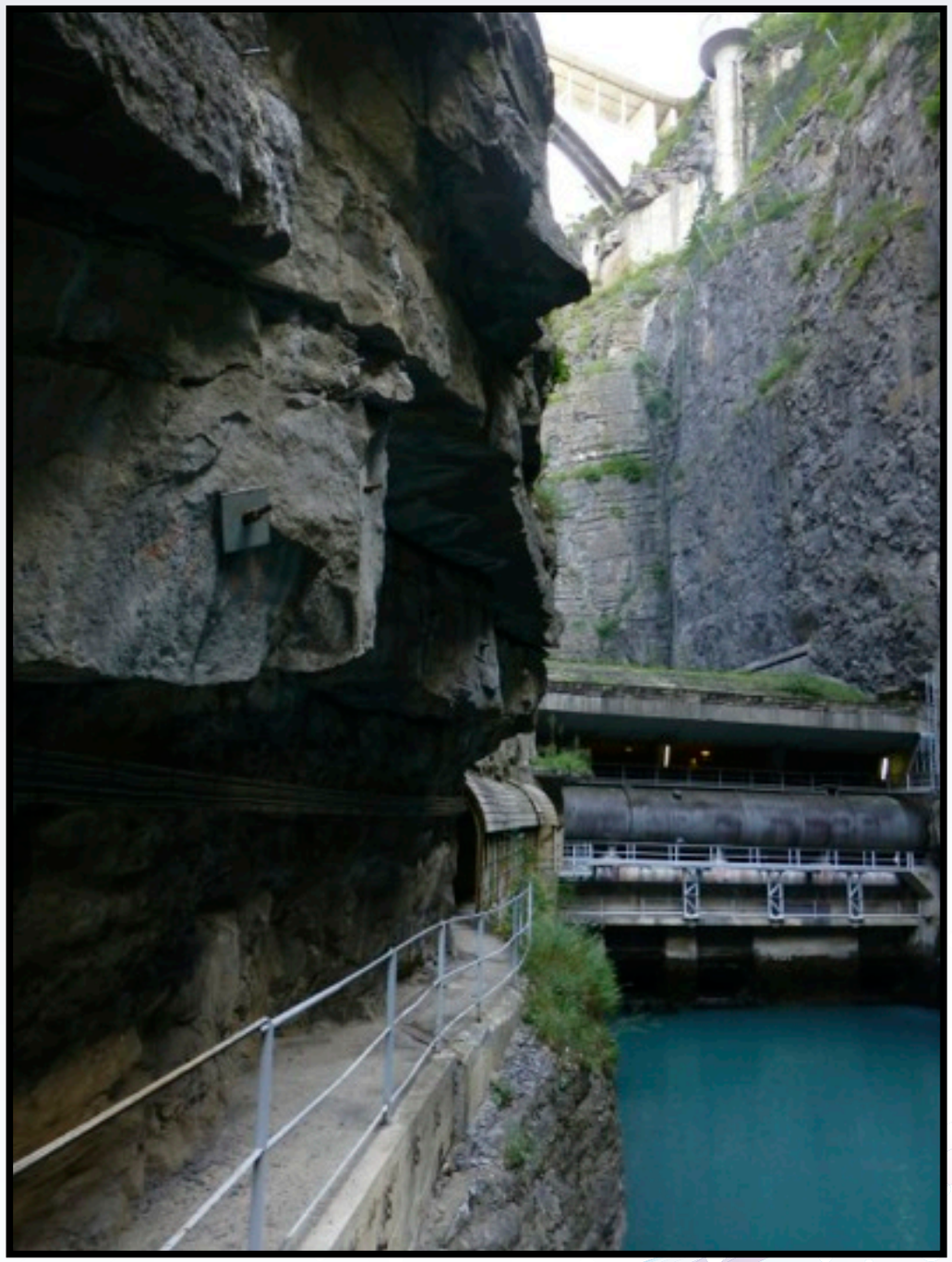
Boadella reservoir.

Multiple Linear Regression strategy

Case study description | MLR construction | Predictability

Multiple Linear Regression strategy

Predictors

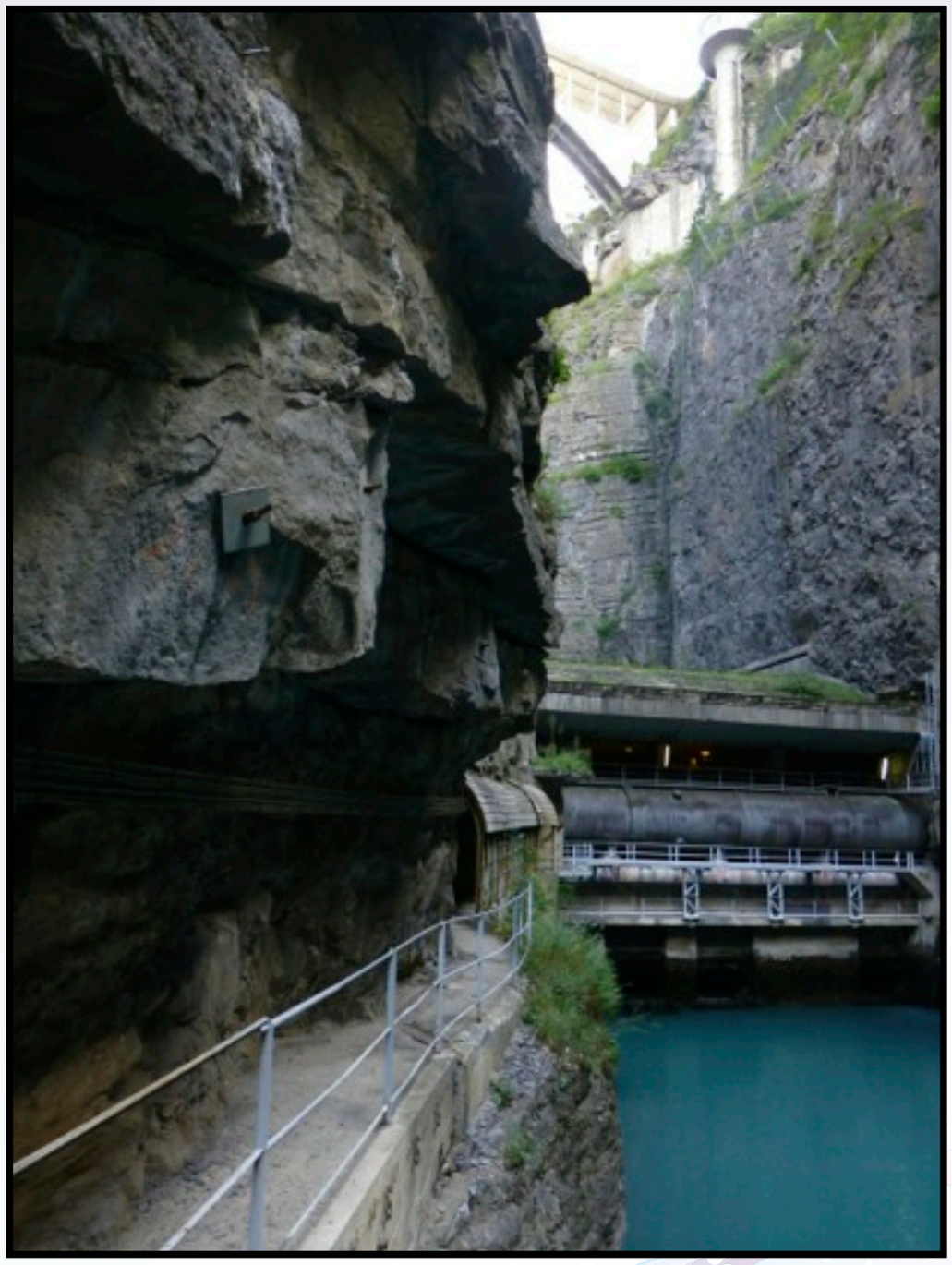


Case study description | MLR construction | Predictability

Multiple Linear Regression strategy

Predictors

- **In-flow**
  - Precip -Tmax - Tmin
- **Volume**
  - In-flow - Tmax - Tmin
- **Out-flow**
  - Vol - Tmax - Tmin



Multiple Linear Regression strategy

Predictors

- ✦ **In-flow**
  - Precip - Tmax - Tmin
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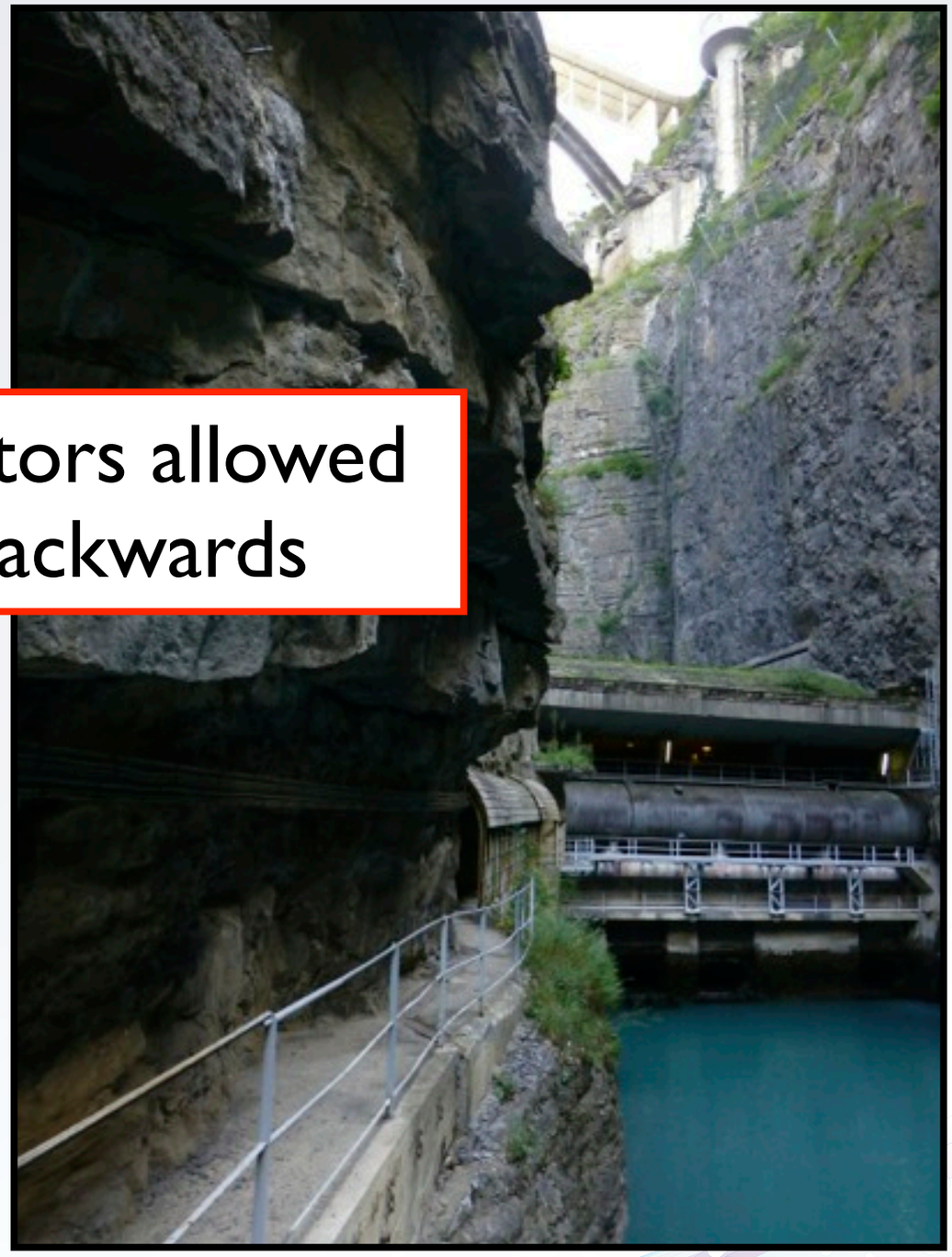
- ✦ **Out-flow**
  - Vol - Tmax - Tmin

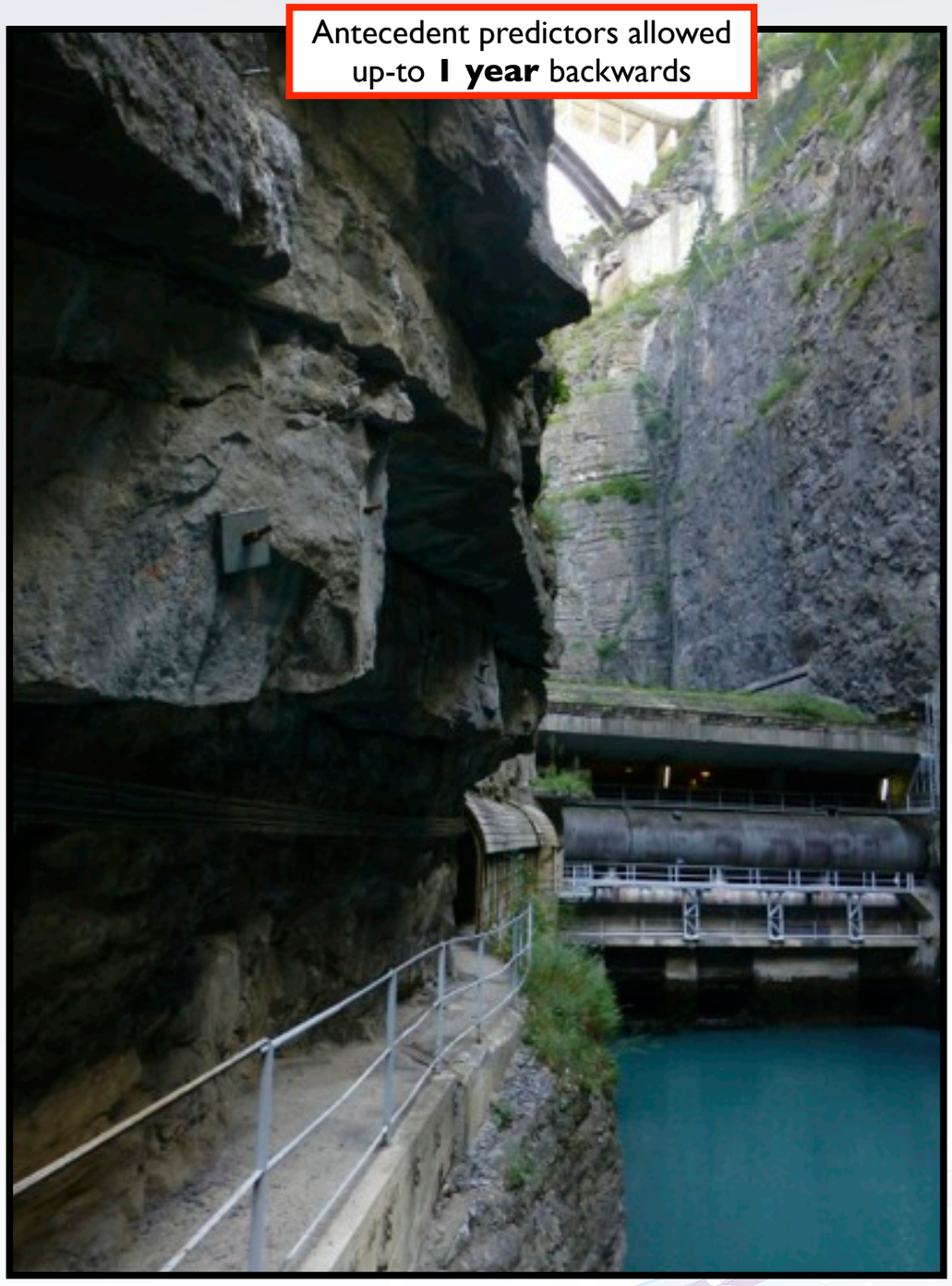
Antecedent predictors allowed up-to **1 year** backwards



Multiple Linear Regression strategy

Predictors

- **In-flow**
  - Precip -Tmax - Tmin
- **Volume**
  - In-flow - Tmax - Tmin
- **Out-flow**
  - Vol - Tmax - Tmin



MLR perfect prognosis

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In-flow

	Best Predictor Combination	R^2
Jan	$\{rr_{(12-12)}, rr_{(1-1)}, Tx_{(1-1)}, Tn_{(10-1)}\}$	0.81
Feb	$\{rr_{(12-12)}, rr_{(1-2)}, Tx_{(6-9)}, Tn_{(11-1)}\}$	0.77
Mar	$\{rr_{(5-8)}, rr_{(1-2)}, Tx_{(7-7)}\}$	0.41
Apr	$\{rr_{(4-4)}, rr_{(12-3)}, Tx_{(6-6)}, Tn_{(5-7)}, Tn_{(8-10)}\}$	0.66
May	$\{rr_{(4-5)}, rr_{(7-7)}, rr_{(10-10)}\}$	0.73
Jun	$\{rr_{(6-6)}, Tn_{(9-9)}, Tn_{(11-11)}\}$	0.63
Jul	$\{rr_{(6-7)}, Tx_{(10-1)}, Tn_{(11-12)}\}$	0.79
Aug	$\{rr_{(7-8)}, Tx_{(1-7)}, Tn_{(10-1)}\}$	0.51
Sep	$\{rr_{(6-9)}, Tx_{(3-3)}, Tn_{(8-8)}\}$	0.31
Oct	$\{rr_{(9-10)}, Tx_{(11-3)}, Tn_{(1-2)}\}$	0.76
Nov	$\{rr_{(11-11)}, rr_{(7-7)}, Tn_{(4-5)}\}$	0.57
Dec	$\{rr_{(10-12)}, Tn_{(5-7)}, Tn_{(8-9)}\}$	0.55

MLR perfect prognosis

Volume

	Best Predictor Combination	R^2
Jan	$\{flwin_{(5-1)}, Tx_{(9-9)}, Tn_{(11-11)}, Tn_{(2-4)}\}$	0.76
Feb	$\{flwin_{(5-2)}, Tx_{(10-10)}, Tn_{(10-11)}\}$	0.69
Mar	$\{flwin_{(5-12)}, flwin_{(2-3)}, Tn_{(9-9)}, Tx_{(6-7)}\}$	0.68
Apr	$\{flwin_{(2-4)}, flwin_{(5-12)}, Tx_{(1-1)}, Tx_{(6-9)}, Tn_{(8-9)}\}$	0.66
May	$\{flwin_{(3-4)}, flwin_{(6-12)}, Tn_{(8-9)}, Tx_{(1-1)}\}$	0.60
Jun	$\{flwin_{(3-4)}, flwin_{(11-12)}, Tn_{(9-9)}, Tx_{(12-1)}, Tx_{(9-9)}\}$	0.66
Jul	$\{flwin_{(3-6)}, flwin_{(7-7)}, Tn_{(6-7)}, Tn_{(9-9)}, Tx_{(9-9)}, Tx_{(7-7)}\}$	0.67
Aug	$\{flwin_{(3-5)}, flwin_{(6-8)}, Tn_{(6-7)}, Tx_{(1-1)}, Tx_{(9-9)}\}$	0.79
Sep	$\{flwin_{(3-6)}, flwin_{(7-8)}, Tn_{(6-7)}, Tx_{(7-8)}, Tx_{(9-9)}\}$	0.76
Oct	$\{flwin_{(3-4)}, flwin_{(6-10)}, Tx_{(1-1)}, Tx_{(10-10)}, Tx_{(9-9)}\}$	0.82
Nov	$\{flwin_{(4-4)}, flwin_{(7-10)}, Tn_{(12-4)}, Tx_{(2-2)}\}$	0.84
Dec	$\{flwin_{(5-12)}, Tn_{(6-7)}, Tx_{(2-2)}, Tx_{(9-9)}\}$	0.83

MLR perfect prognosis

Out-flow

	Best Predictor Combination	R^2
Jan	$\{rr_{(10-1)}, Tx_{(11-1)}\}$	0.60
Feb	$\{rr_{(1-2)}, Tx_{(7-9)}, Tn_{(1-1)}\}$	0.86
Mar	$\{rr_{(7-8)}, vl_{(12-2)}\}$	0.42
Apr	$\{rr_{(10-2)}\}$	0.32
May	$\{rr_{(4-5)}, vl_{(10-4)}\}$	0.55
Jun	$\{vl_{(3-4)}\}$	0.33
Jul	$\{Tx_{(4-4)}, Tn_{(10-11)}, vl_{(3-5)}\}$	0.75
Aug	$\{vl_{(3-5)}, vl_{(6-6)}, vl_{(7-7)}\}$	0.90
Sep	$\{Tx_{(5-6)}, vl_{(7-7)}, vl_{(8-8)}\}$	0.85
Oct	$\{rr_{(1-4)}, rr_{(6-6)}, Tn_{(7-7)}\}$	0.51
Nov	$\{rr_{(1-6)}, Tn_{(4-5)}\}$	0.18
Dec	$\{rr_{(10-12)}, Tx_{(9-11)}, Tn_{(10-12)}\}$	0.18

Forecasting strategies

Case study description | MLR construction | Predictability

Forecasting strategies

- ✦ Climatology

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Forecasting strategies

- Climatology
- Persistence

Forecasting strategies

- ✦ Climatology
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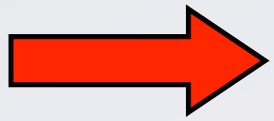
- ✦ Antecedent + Climatology (MLR)
- ✦ Antecedent + BC S4 (MLR)
- ✦ Antecedent + MOS-analog S4 (MLR)
- ✦ Antecedent + LR S4 (MLR)

Forecasting strategies

- Climatology



Current **operational** approach

- Persistence
- Antecedent + Climatology (MLR)
- Antecedent + BC S4 (MLR)
- Antecedent + MOS-analog S4 (MLR)
- Antecedent + LR S4 (MLR)

Economic Value

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Preventive Action \ Ocurrence	Yes	No
Yes	αC	βC
No	γL	0

$$EV = \frac{TE - TE_{\text{clim}}}{TE_{perf} - TE_{\text{clim}}}$$

Economic Value

Preventive Action \ Ocurrence	Yes	No
Yes	αC	βC
No	γL	0

$$R = C/L$$

$$EV = \frac{H\ p_c\ R + F\,(1 - p_c)\,R + (1 - H)p_c - \min\{R, p_c\}}{p_c R - \min\{R, p_c\}}$$

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Economic Value

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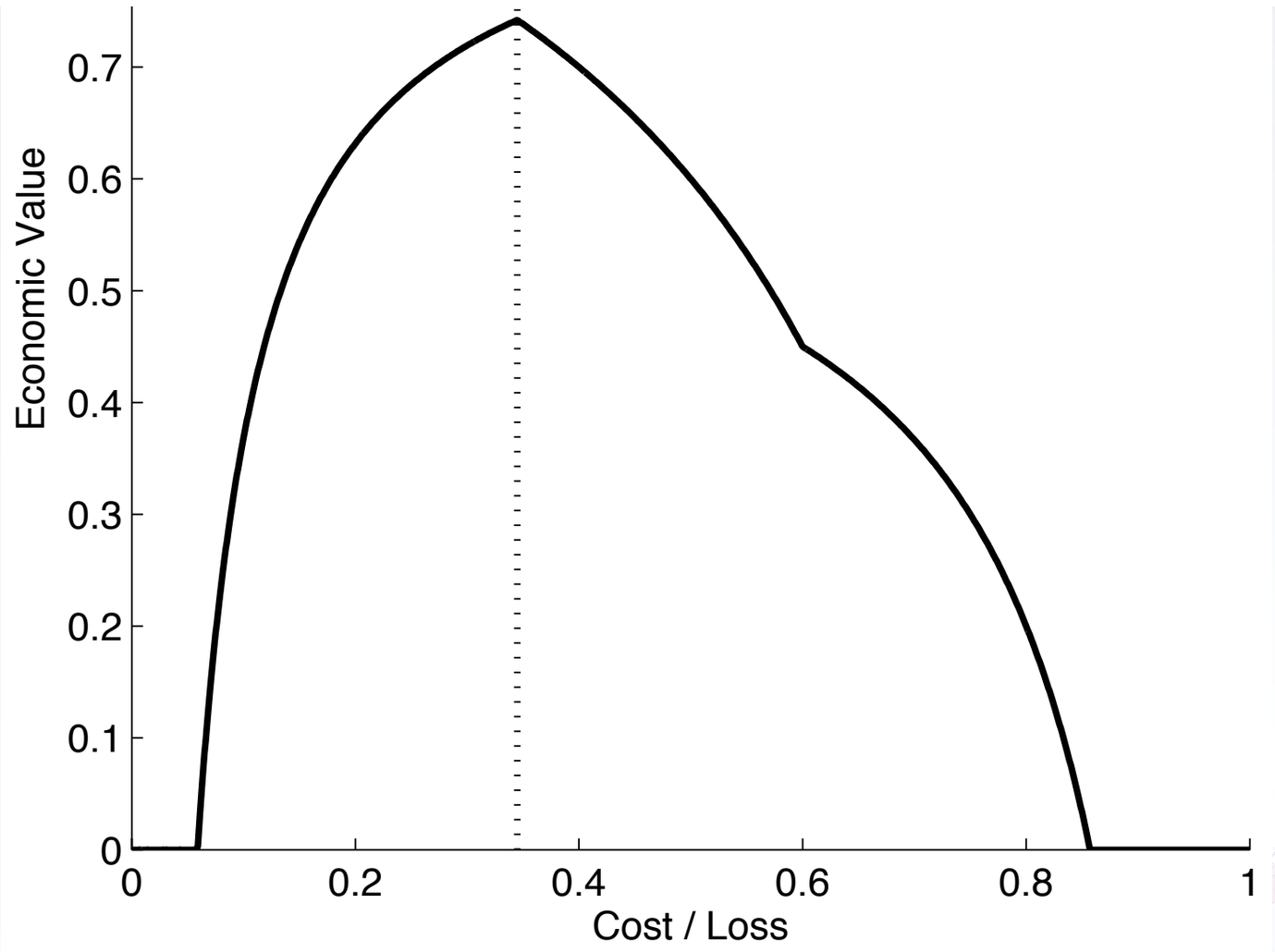

Seasonal forecast (volume)

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Economic Value (July - Lead 5 - Humid conditions)

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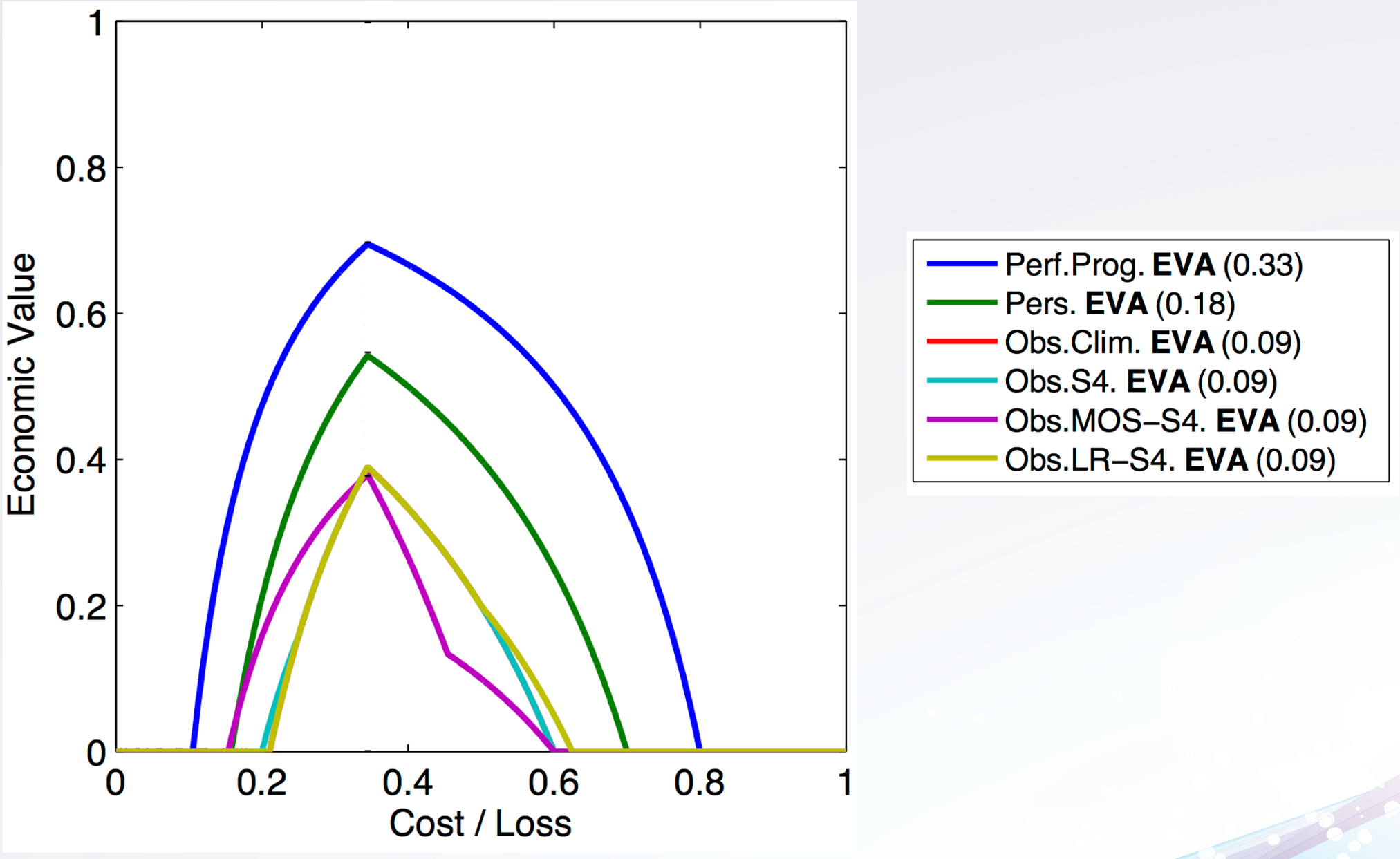

Seasonal forecast (volume)

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EV - 12 month - 7 lead

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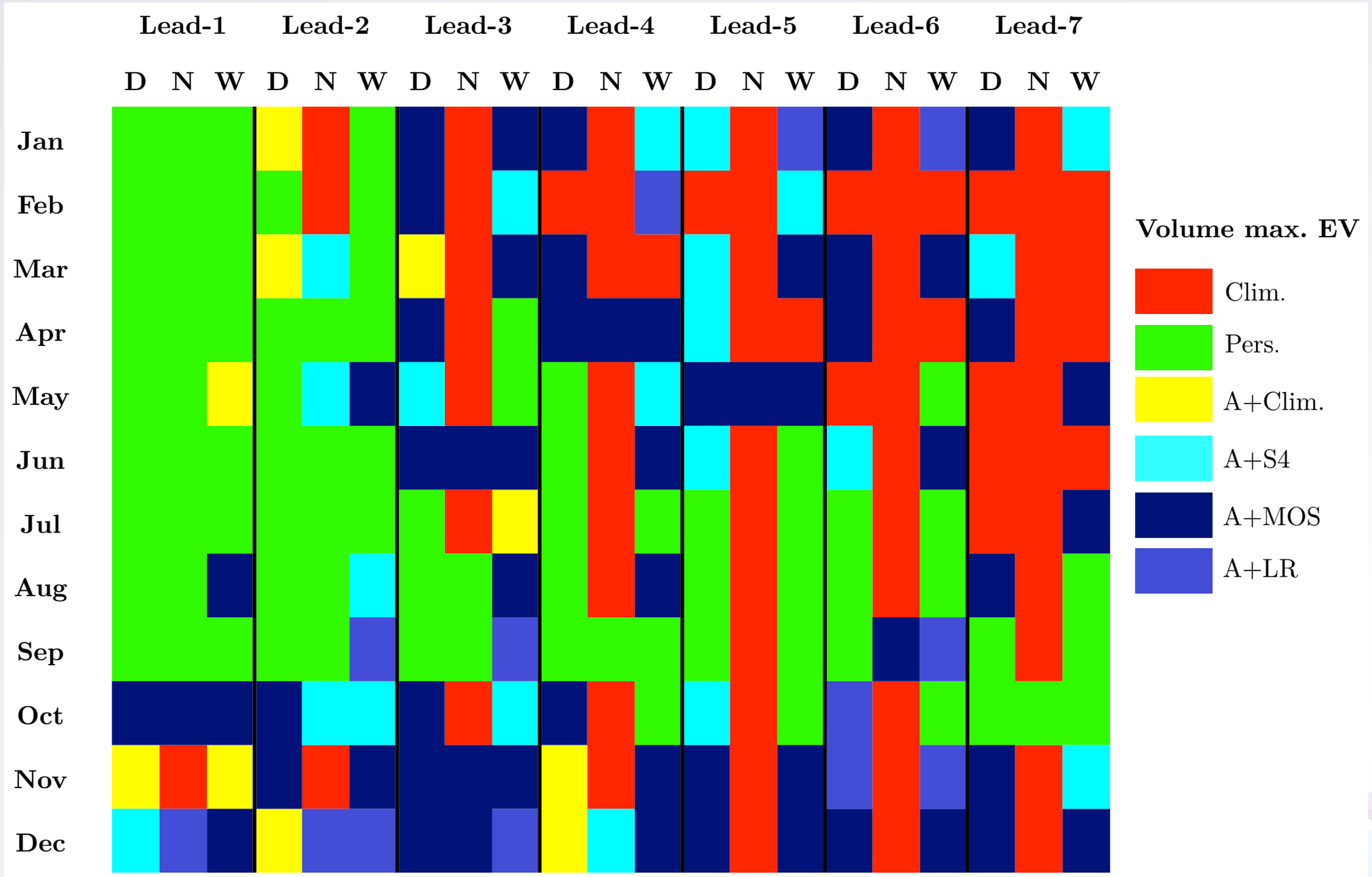

Case study description | MLR construction | Predictability

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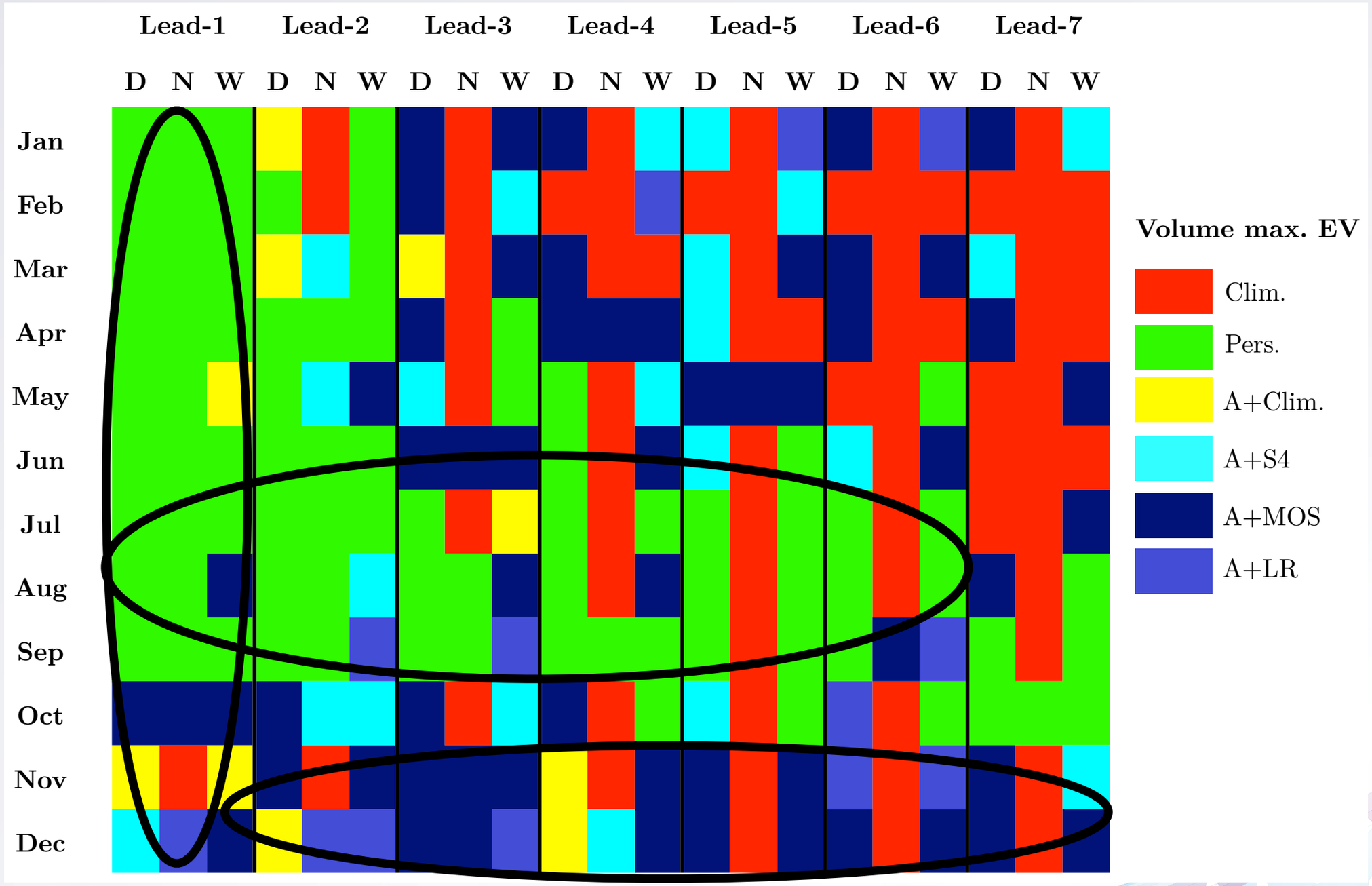
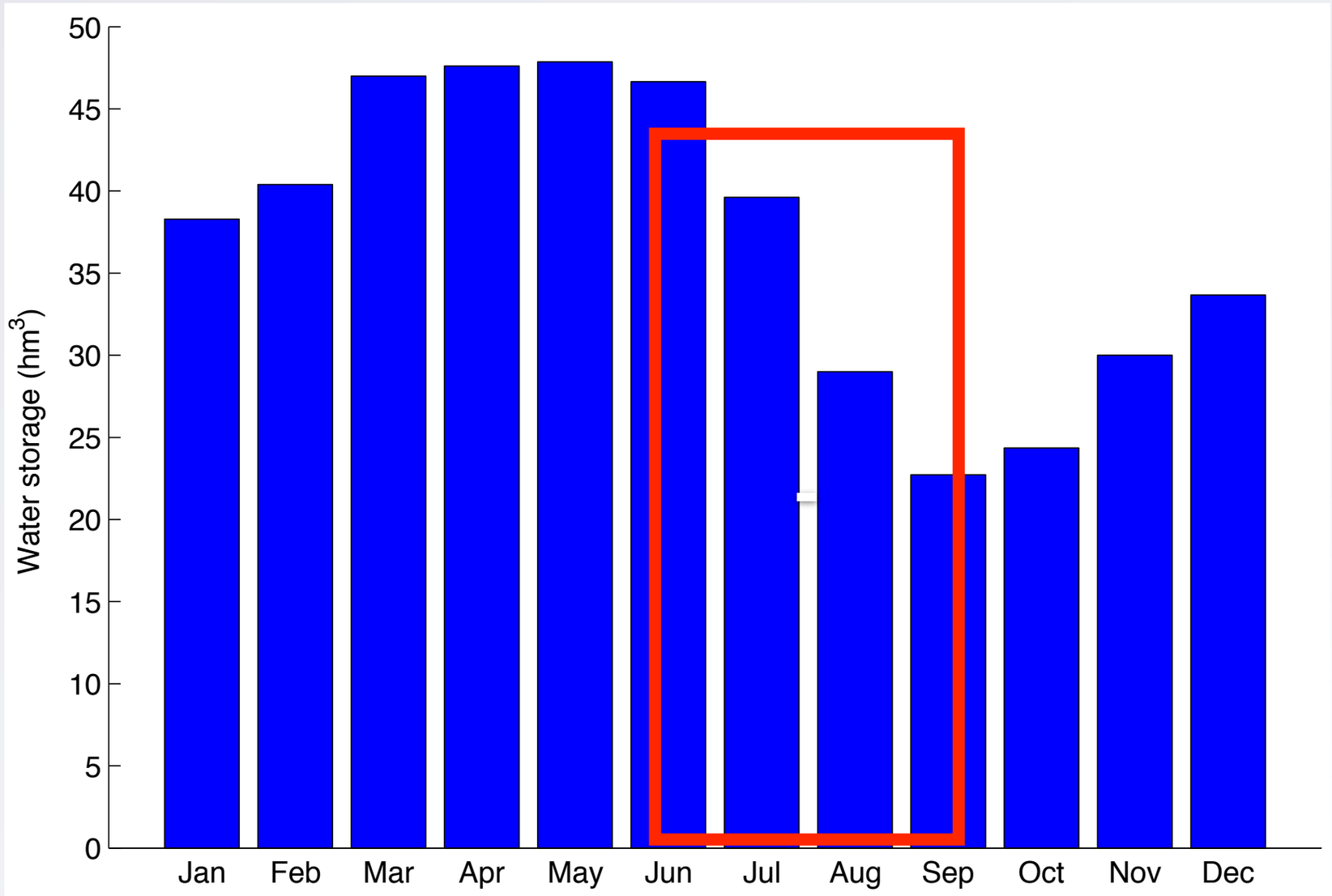
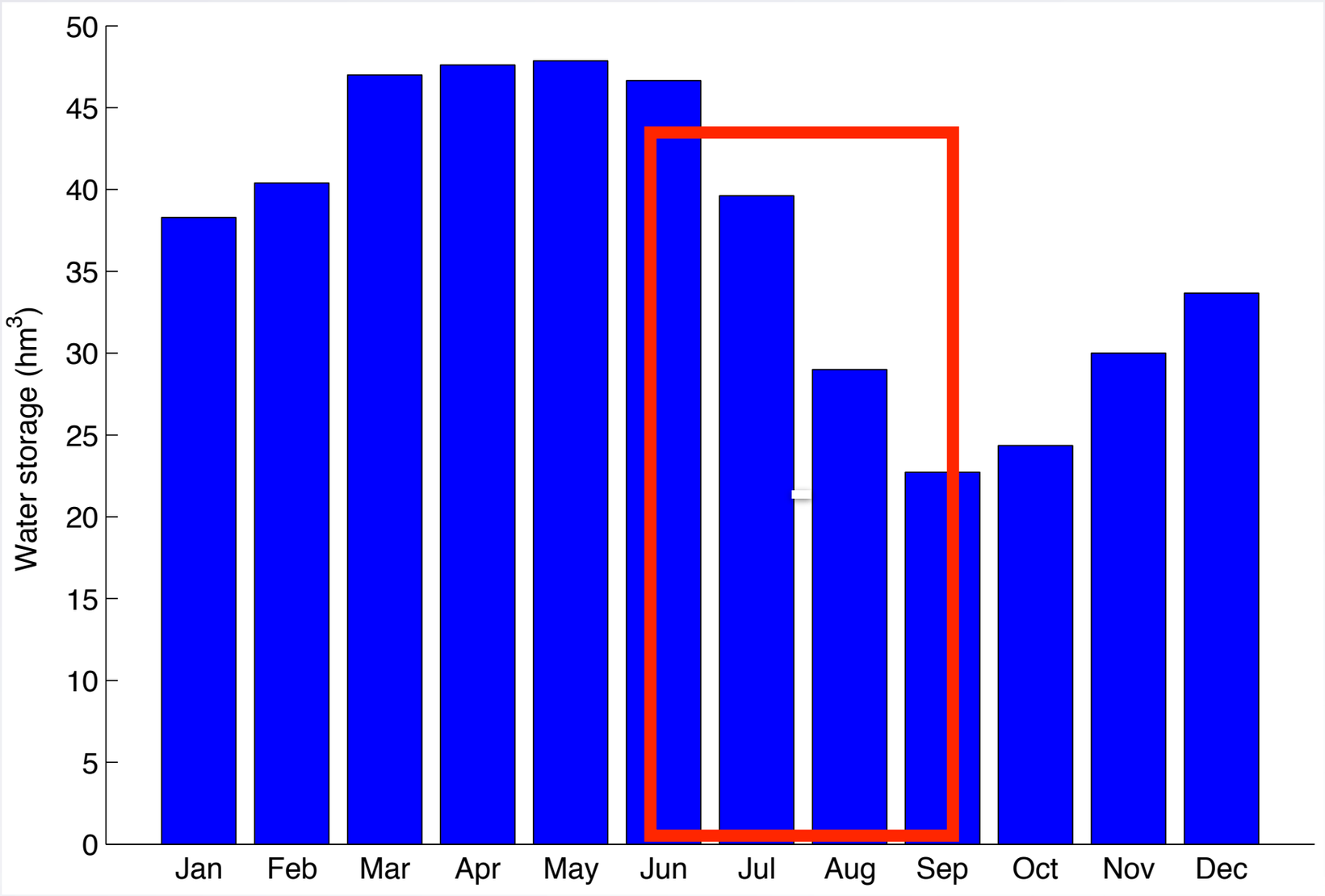




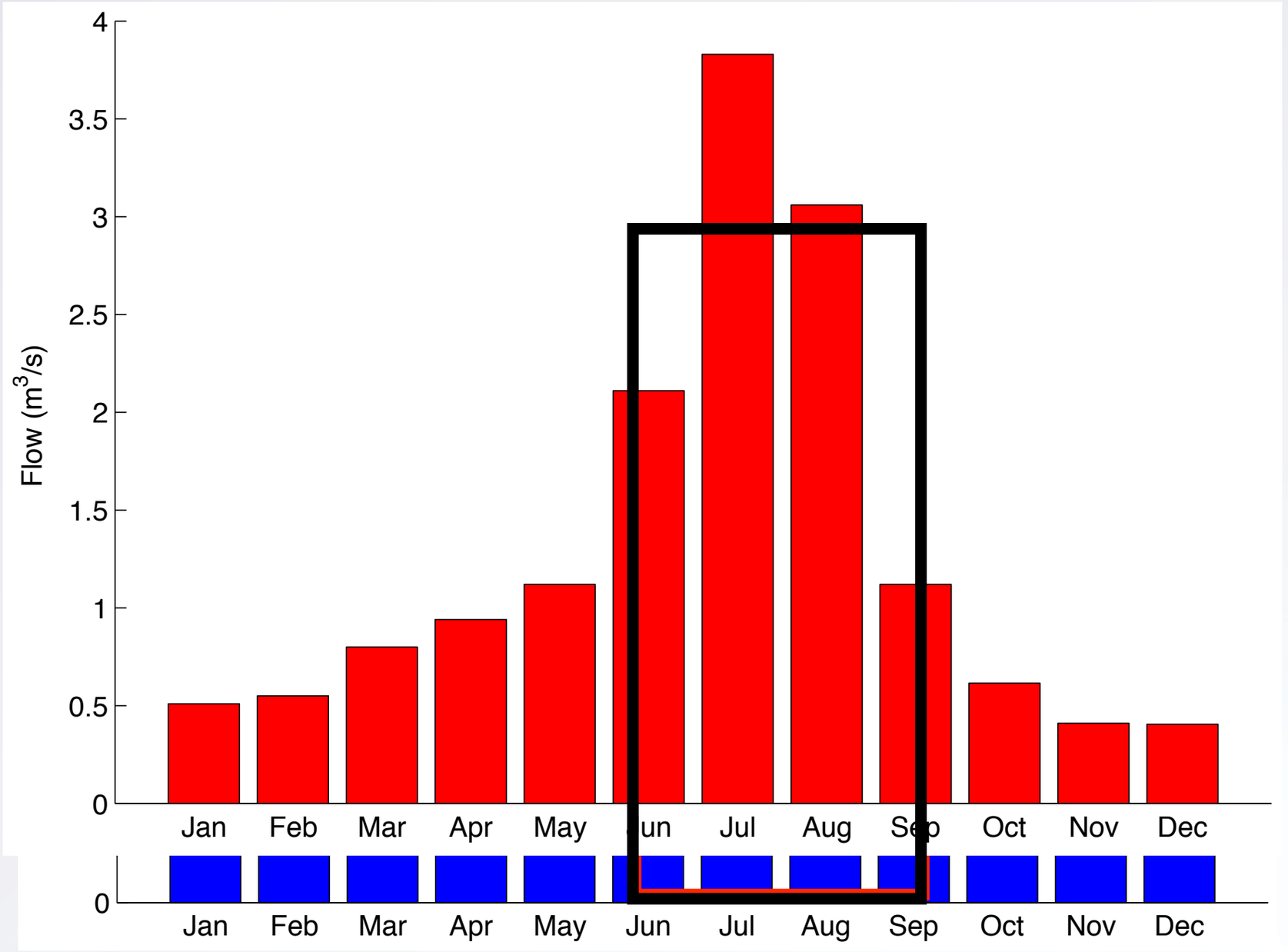
Case study description | MLR construction | Predictability

Climatology: volume



Case study description | MLR construction | Predictability

Climatology: out-flow



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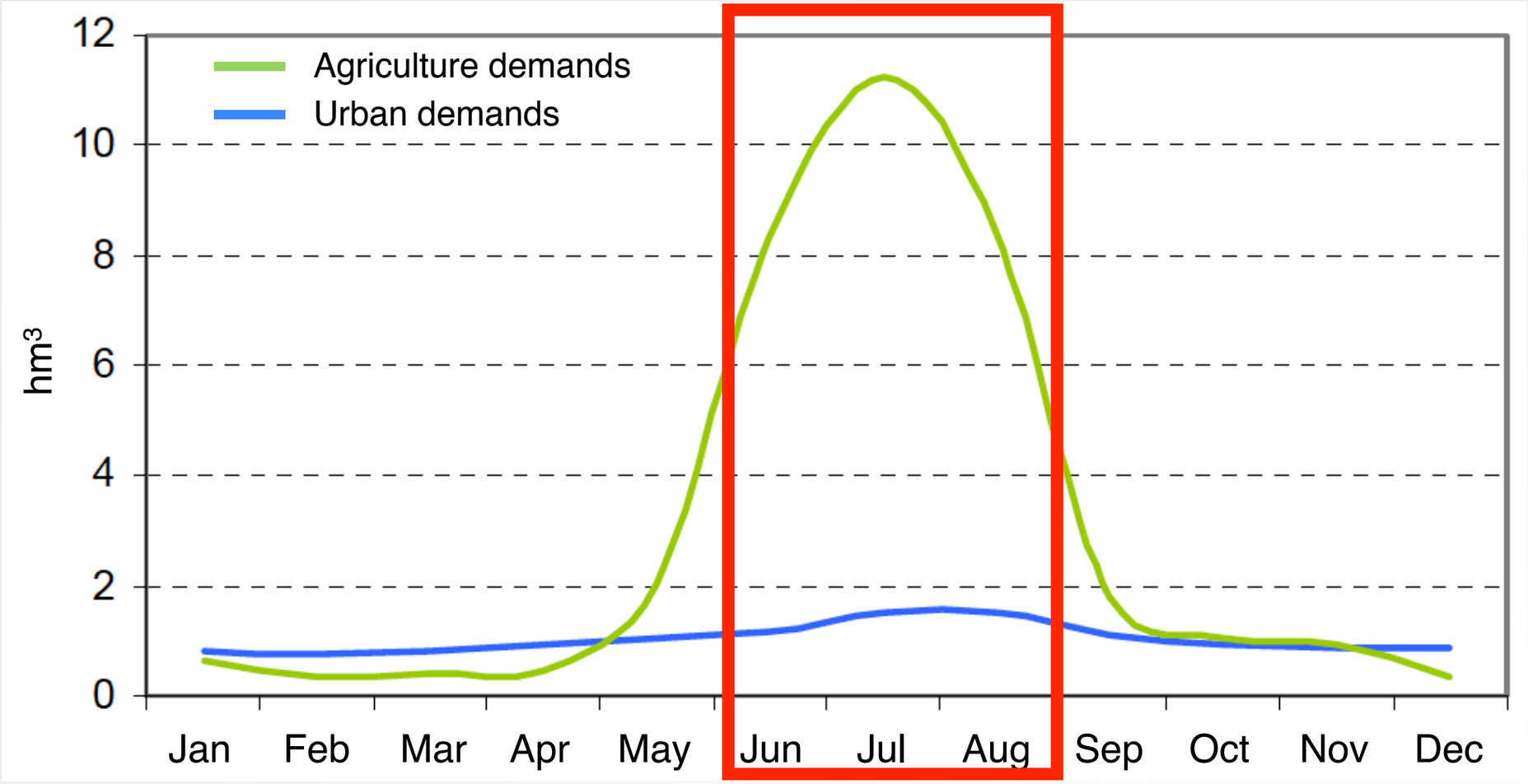
Climatology: demands



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Synthesis: Seasonal forecast of water resources

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✦ In-flow

- Predictability beyond climatology generally restricted to **lead one**

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- Predictability beyond climatology up to **lead four** in all months but February
- Positive Economic Value up to **lead seven** from August to January

Synthesis: Seasonal forecast of water resources

✦ In-flow

- Predictability beyond climatology generally restricted to **lead one**

✦ Volume

- Predictability beyond climatology up to **lead four** in all months but February
- Positive Economic Value up to **lead seven** from August to January

✦ Out-flow

- Predictability beyond climatology at **lead one** for almost all months
- From August to October enhanced predictabilities up to **lead seven**

Take home messages:

Seasonal forecast of water resources

Take home messages:

a) Generally, all the three variables can be **successfully** modelled with **MLR** in perfect prognosis conditions. **Volume** is the best modelled variable, followed by **in-flow** and **out-flow.**

b) **Summer** seasonal forecasts with skill beyond climatology can be issued from a minimum of **four months** in advance for volume and out-flow variables.

Thank you for your attention!

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Outline

1. Case study description

2. MLR construction

3. Predictability