Reservoir optimisation using El Niño information

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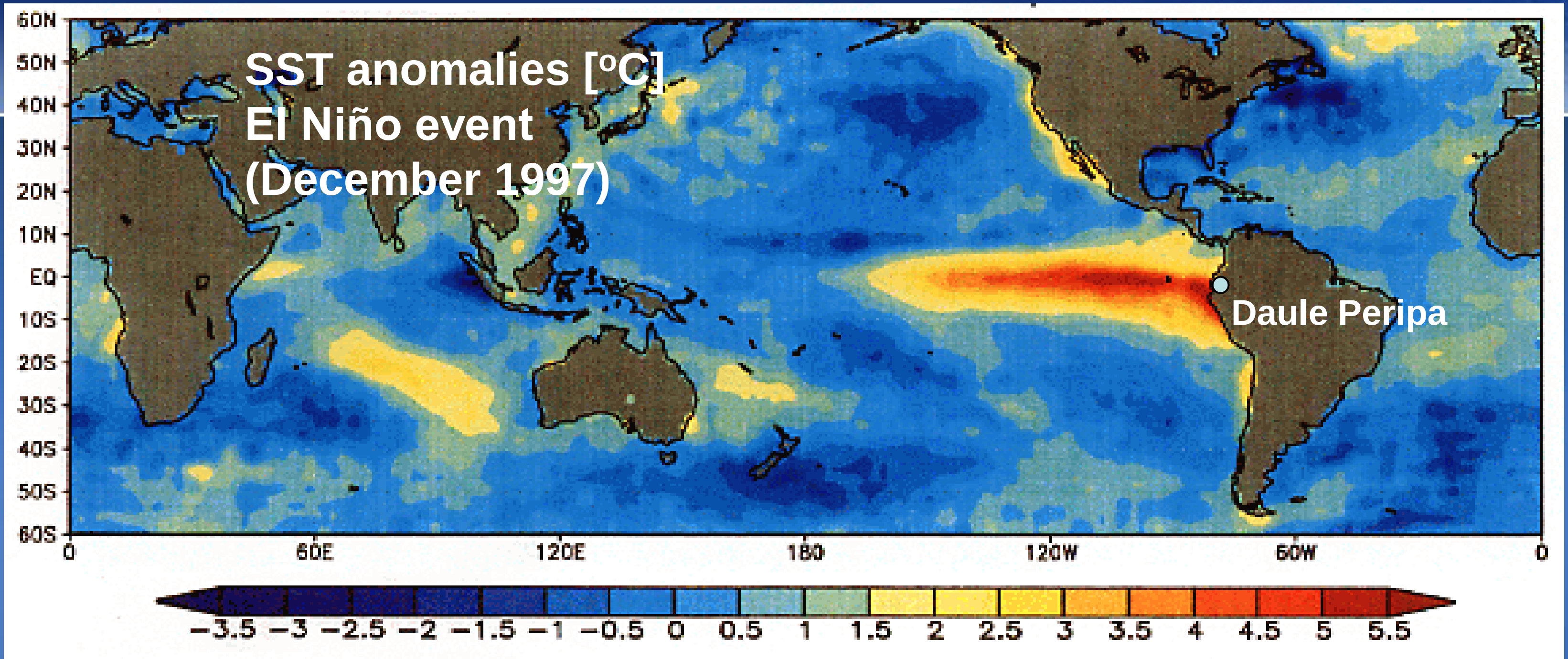
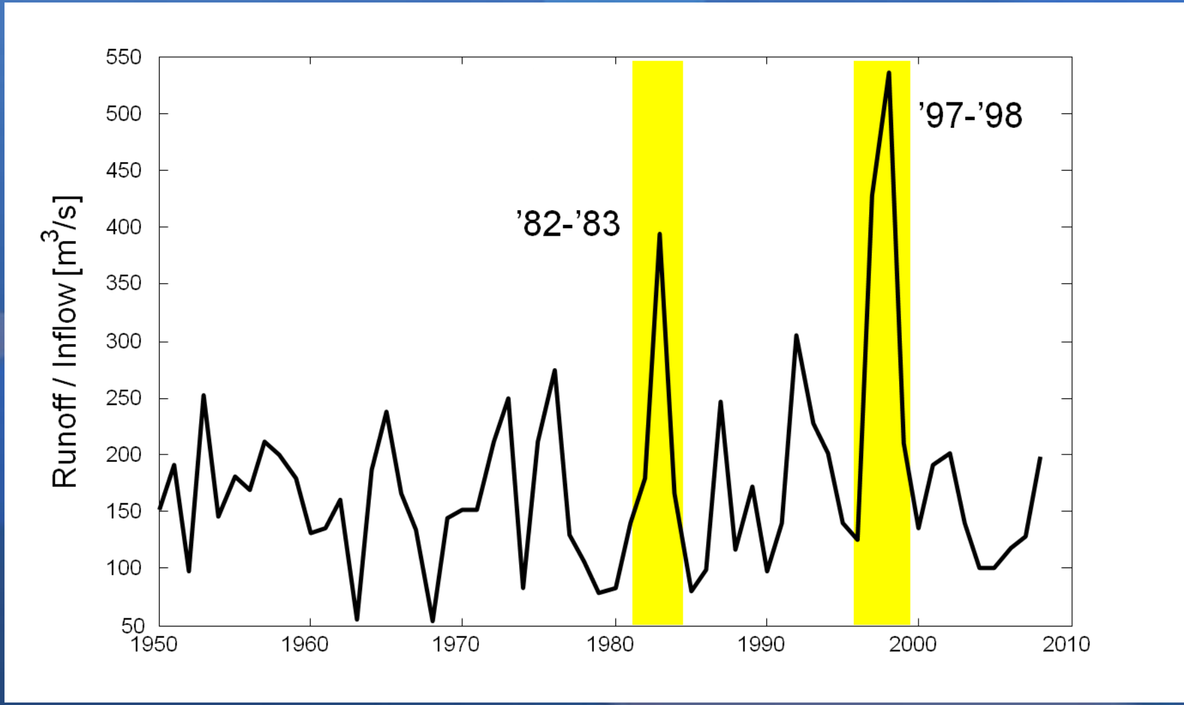
HydroPredict 2010, 20-23 September 2010, Prague, Czech Republic

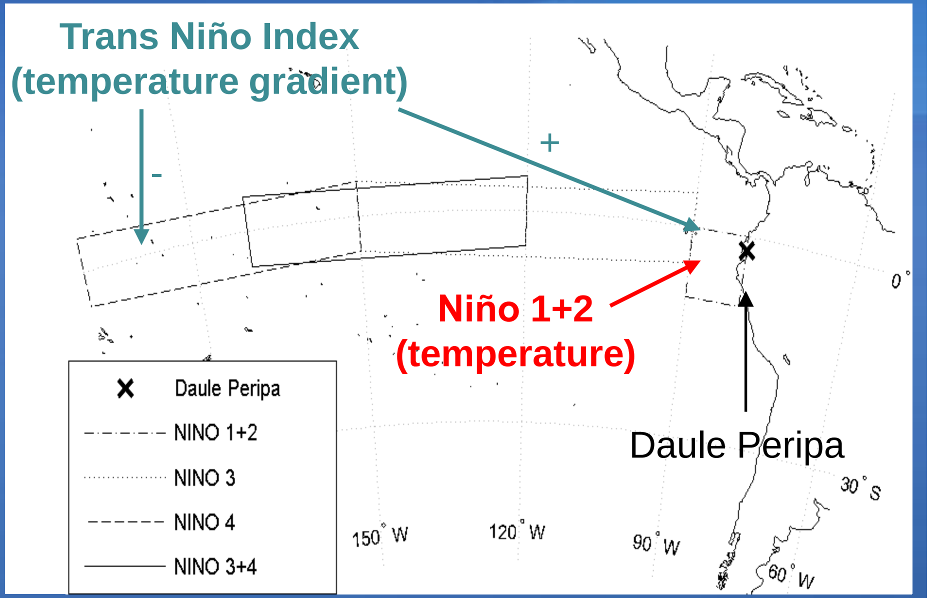


Correlation between El Niño events and streamflow regime

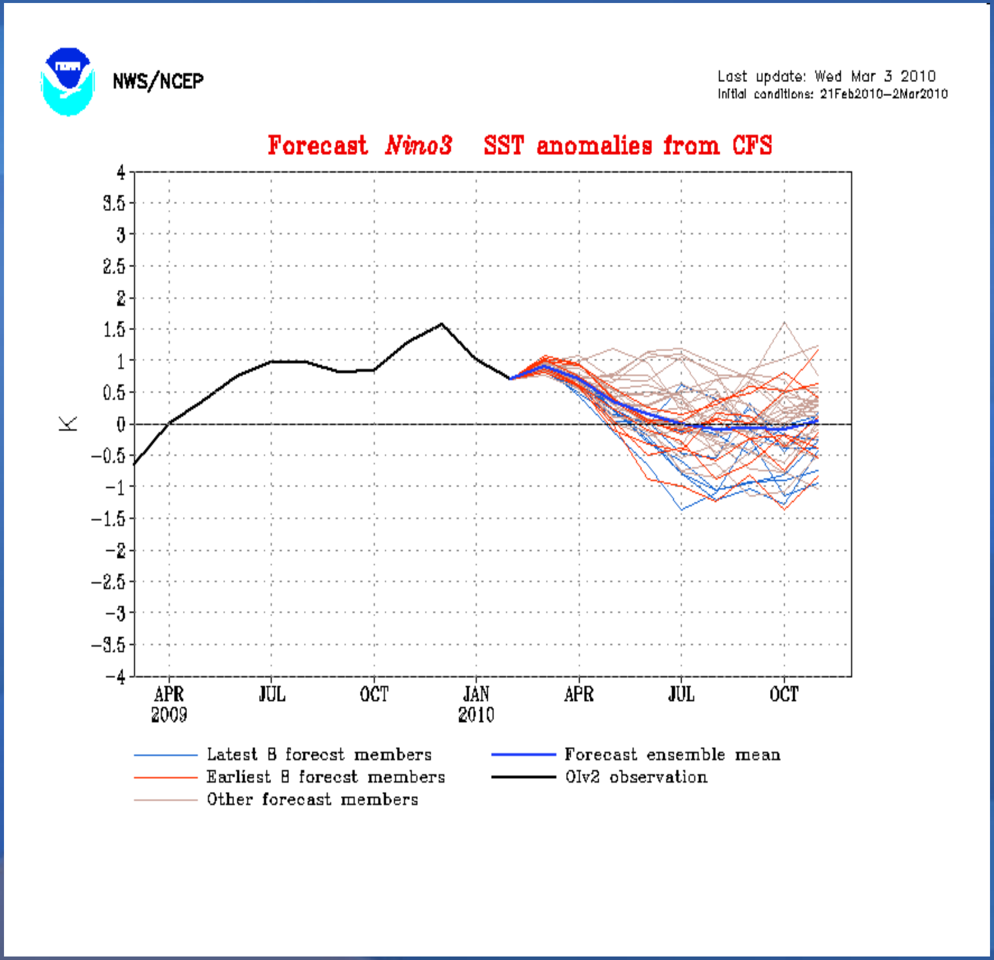


El Niño indices

Standard indices



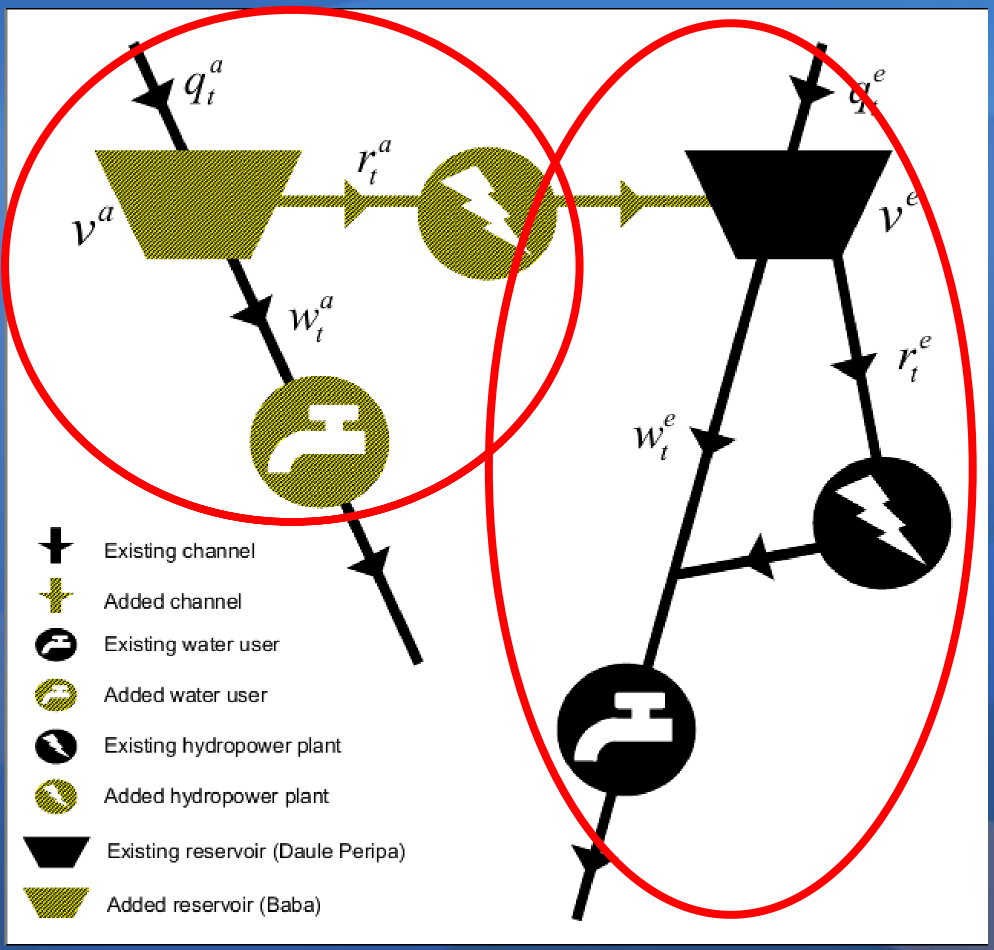
Forecasts



Optimisation of reservoir system

Planned extension: Baba diversion

Existing: Daule-Peripa



Optimisation objectives:

- Maximise hydropower
- Minimise downstream water deficits

Stochastic optimisation:

- Stochastic inflow model
- Reservoir simulation model
- NSGA-II optimisation algorithm

Stochastic inflow model

Markov switching autoregressive model:

- Streamflow driven by a hidden climate state process
- Transition between states follow a first order Markov process
- Transition probabilities depend on climate state
- Streamflow modelled by an ARX model conditioned on climate state

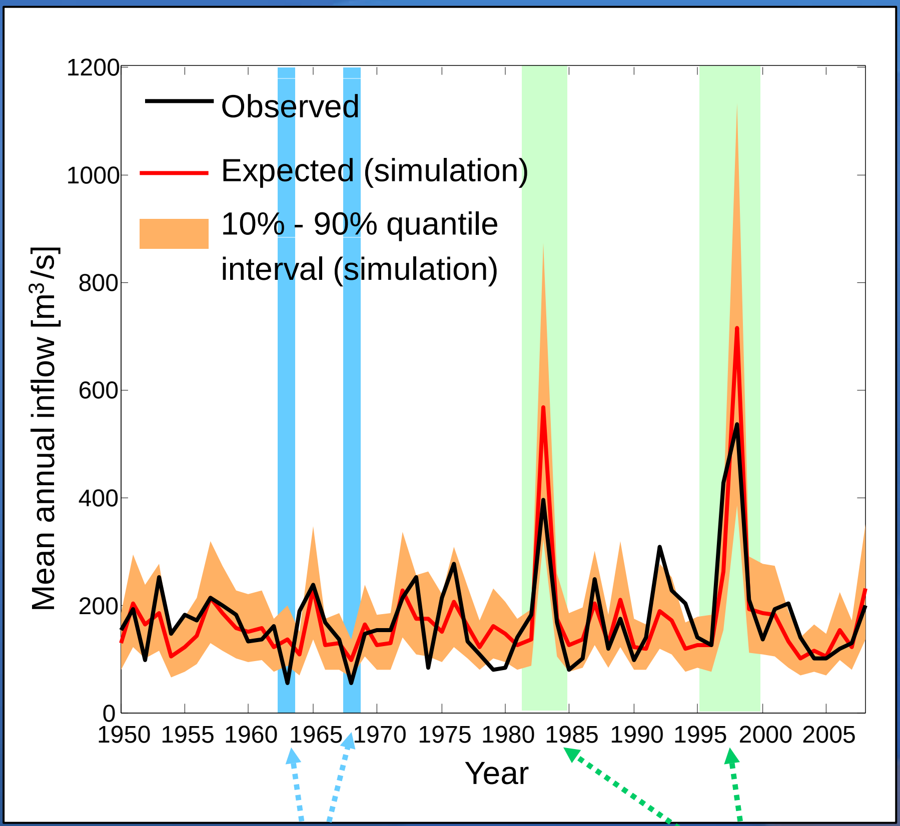
Estimation for Daule-Peripa inflow:

- Niño 1+2 and trans-Niño indeces
- Two state model

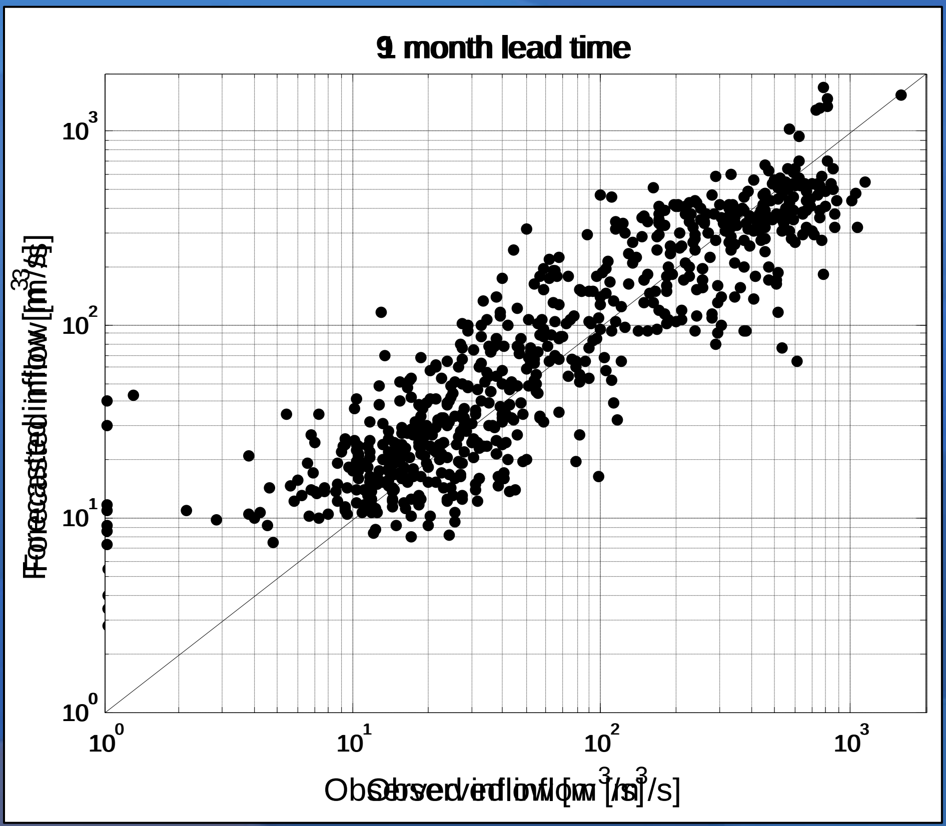
Gelati et al., WRR, 2010

Inflow model results

Simulation



Forecasts (expected values)



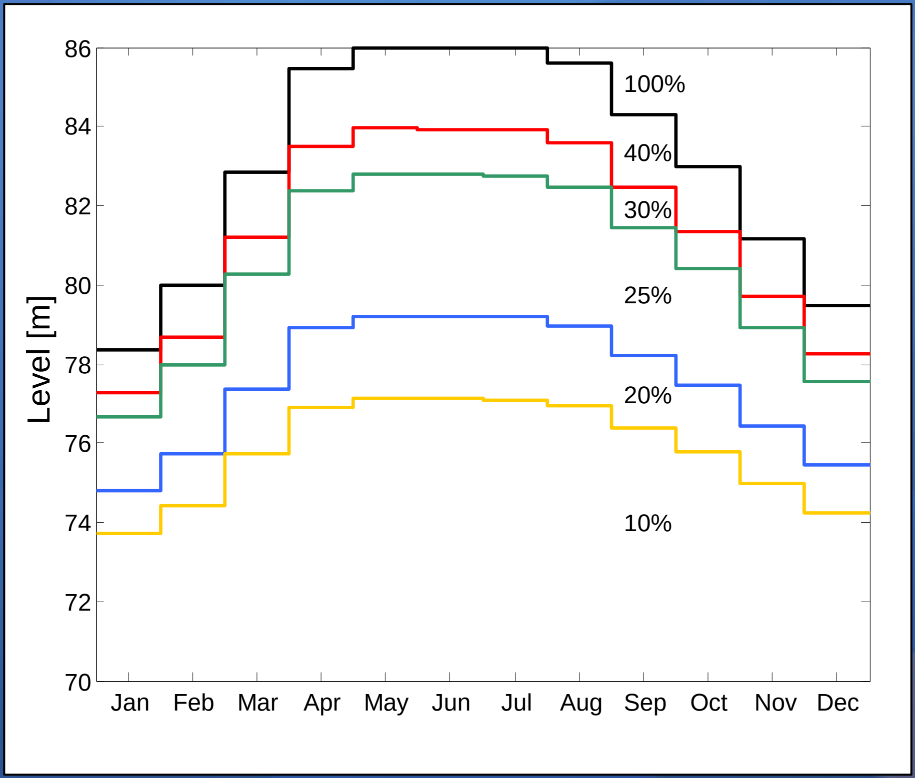
Dryest years

Major El Niño events

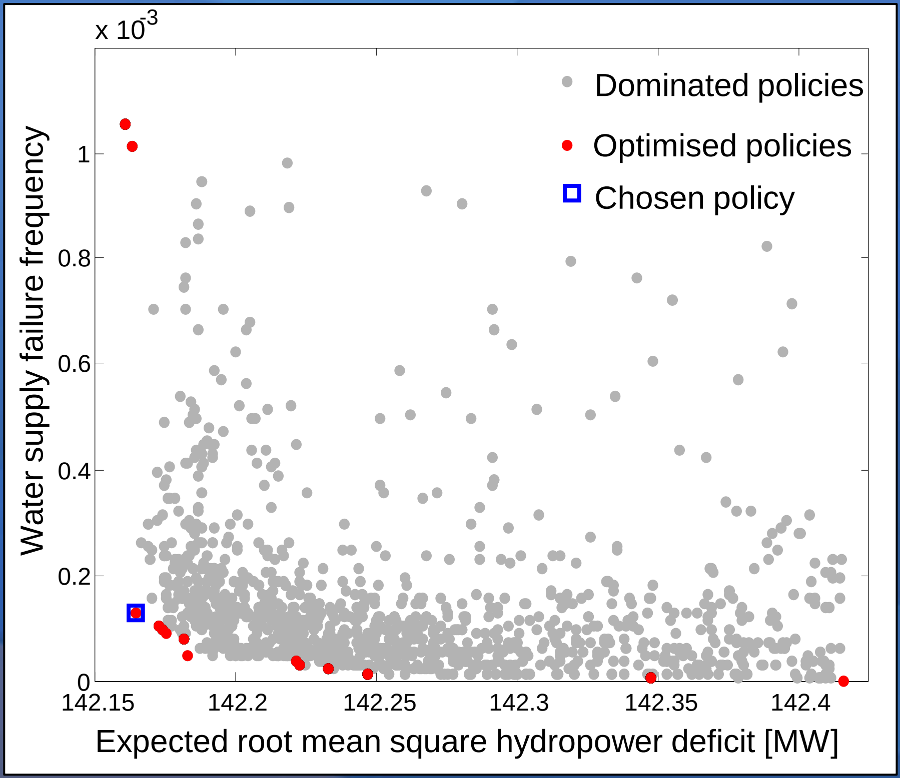
Rule curve optimisation

Release = f (storage, month, hydropower water demand)

5 curves → 12+4 decision variables



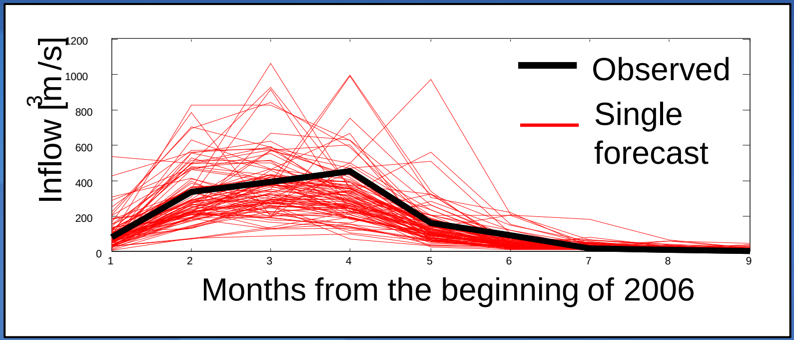
Chosen policy with water supply failure frequency < 10^{-3}



Real-time optimisation using inflow forecasts

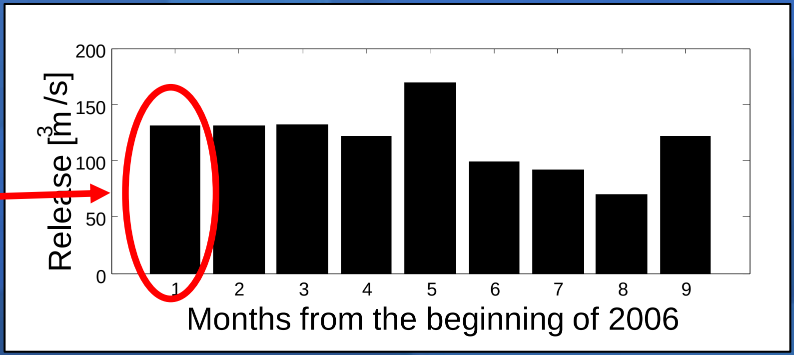
At each time step:

1. Generate 100 series of 9-month long inflow forecasts (given past inflow and El Niño forecasts)



2. Optimise 9 monthly releases (optimise hydropower in 9-month period and penalise future costs/benefits)

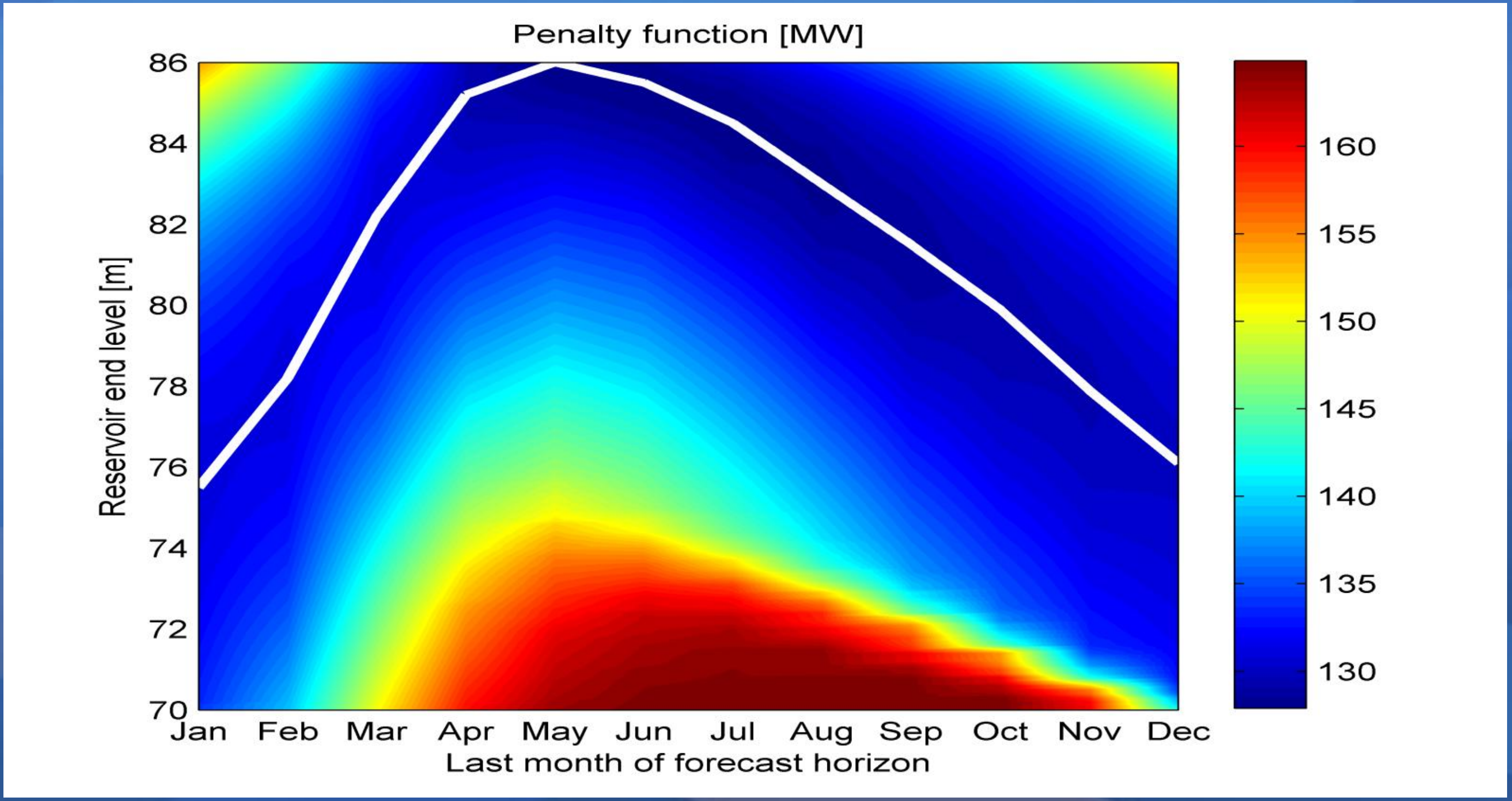
3. **Implement the first release**



4. Go to the next time step…

Penalty function – storage target

Expected optimal hydropower production in a twelve-month period as function of the month and reservoir level (Dynamic Programming on 1950-1999 period)



Optimisation results existing system

	Root mean square hydropower deficit [MW]	Water supply failure frequency	Average generated power [MW]
Historical	147.0	0	70.6
Rule curves	144.7	0	71.4
Forecast	142.9	0	73.1
Dynamic programming	139.8	0	74.6

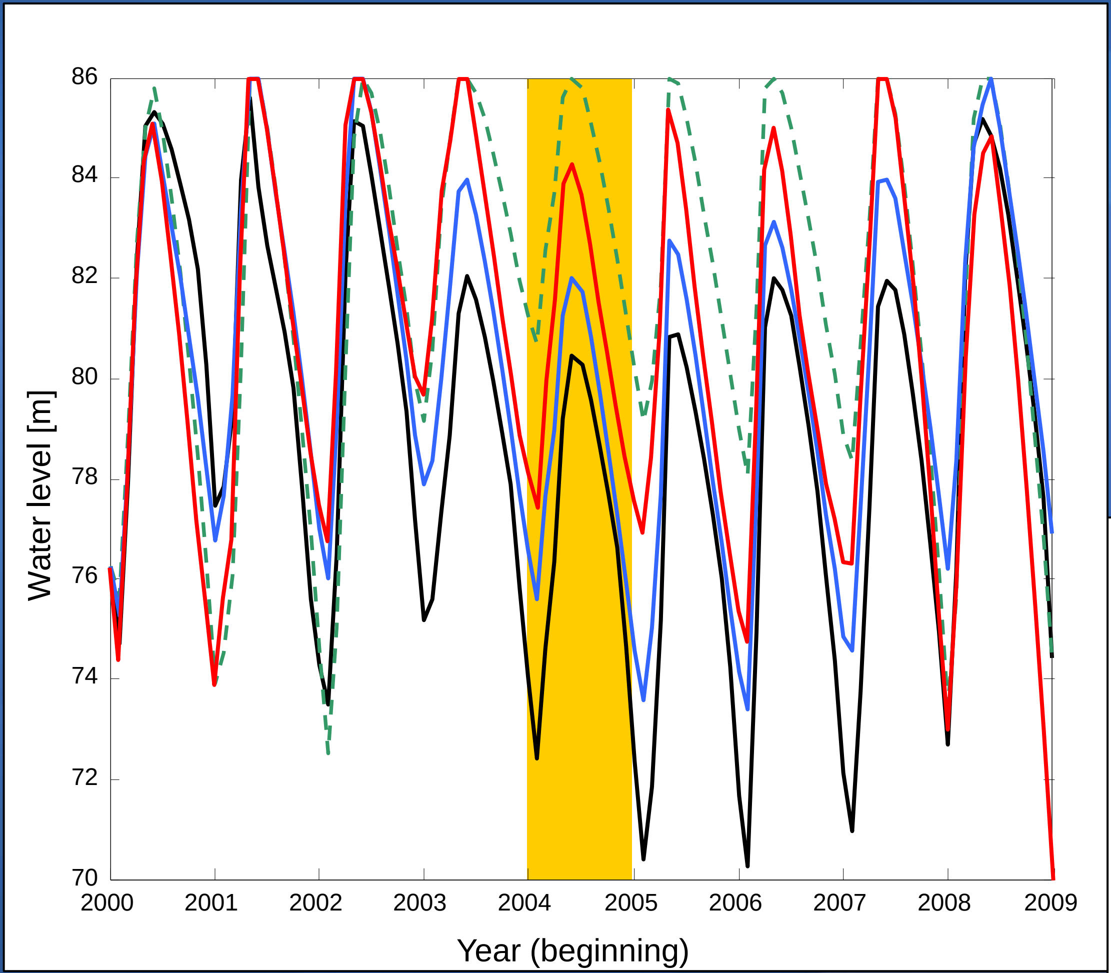
1.1%

3.5%

5.7%

Optimisation results existing system

Reservoir water level (monthly)

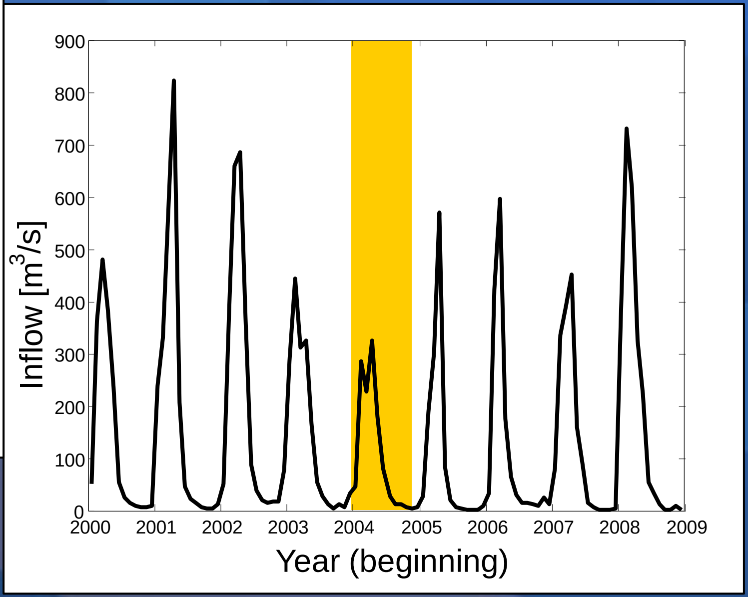


Dyn. programming

Historical operation

Rule curves

Forecasts



Optimisation results extended system

	Average generated power Daule Peripa [MW]	Average generated power Baba [MW]	Average generated power Total [MW]
Historical - existing	70.6	-	70.6
Forecast optimisation - existing	73.1	-	73.1
Dynamic programming - existing	74.6	-	74.6
Forecast optimisation - extended	129.0	26.3	155.3
Dynamic programming - extended	133.3	26.0	159.3

Increase in average production with extended scheme: 108%

Concluding remarks

- Stochastic simulation-optimisation approach using inflow model with climatic indices as covariate information
- Using El Niño information has a large potential for improving the current reservoir management

- General stochastic model
  - Use with other large scale climatic information
  - Apply as downscaling and impact assessment tool for climate change studies

Thank you for your attention

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