# Statistical Modelling of Inflow series

Sara Martino

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# About the project:

NR (Norske Regnesentral) and SINTEF Energy

**Time frame**: 2 years (2012-2014)

**Budget**: 2.8

**Partners**: NVE, Statnett, E-Co Energi AS, Lyse  Handel AS, Agder Energi Produksjon

# Building future scenario for Inflow series: Motivation and Current Practice

- Production planning needs to deal with uncertainty over future Inflow
  - Long period: investment analysis, …
  - Middle period: seasonal planning, predict extreme situations, …

- Today's practice is  to build scenarios resampling from historical data:
  "what happened before can happen again"
  - Inflow series are typically 50-80 years long
  - In the new data base from NVE there are 82 inflow series for Norway

# Current practice: pros and cons

- The scenarios are realistic
- It gives a good picture of the "average" inflow profile
- The inflow series have the correct correlation structure both in space and time
- The method is robust

**BUT**

- The variability of the inflow profile is not well estimated
- Extreme situations are represented only through 1 or few years
- It is not possible to simulate situations more extreme than those observed
- Trends (for example climate change but also possible "long cycles") are difficult to deal with
- There are many location where there is no observed inflow

# Can statistical modelling help to get better scenario?

- A statistical model can describe uncertainty at different levels (trend, seasonal variations, etc)
- It is possible to simulate from a statistical model thus allowing for a better understanding of extreme situations, eg probability of curtailment (initial motivation of the project)
- Prerequisite for consistent stochastic optimization
- Geostatistics can be used to sample inflow series in location without observations
  (not in this project)

# Statistical Model for Inflow series:

- The model is build only on time series of Inflow data (with-out explaining the underlying hydrological and meteorological processes that generate the inflow)
- Data Used:
  - Weekly measured inflow (m^3/s) for a set of 84 monitored locations.
  - Energy series (GWh) for 13 price areas, computed using the EMPS model with the NVE system description.
- Focus on:
  - Accumulated Inflow over 4, 13 or 26 weeks
  - Extreme situations (dry or wet spells)
- We built both univariate and multivariate models
- Model Validation:
  - Comparison between simulated and observed inflow
  - Comparison of results from EMPS when fed with simulated and observed inflow series

# Univariate Statistical model for Inflow Series

Inflow = Trend + Residuals

Deterministic part of the model:

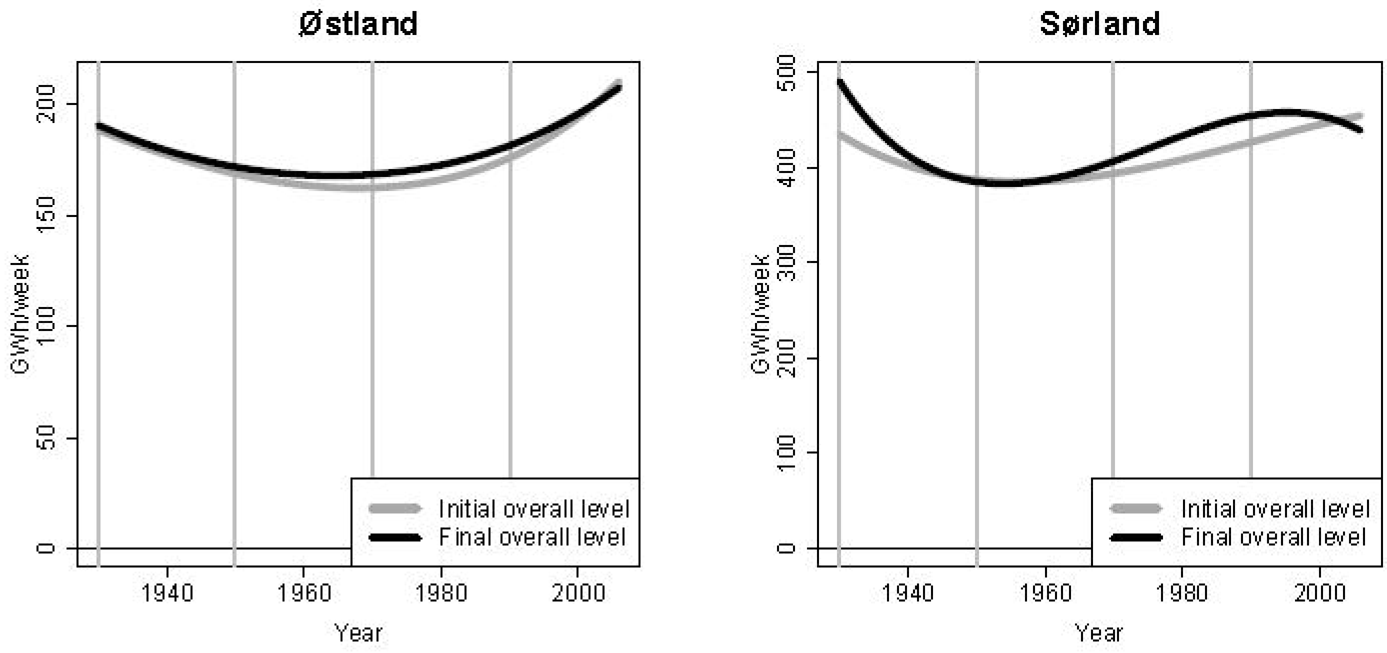
Slowly varying mean +
Seasonality +
Slowly varying seasonality

Stochastic part of the model:
Describes the departure from the trend.

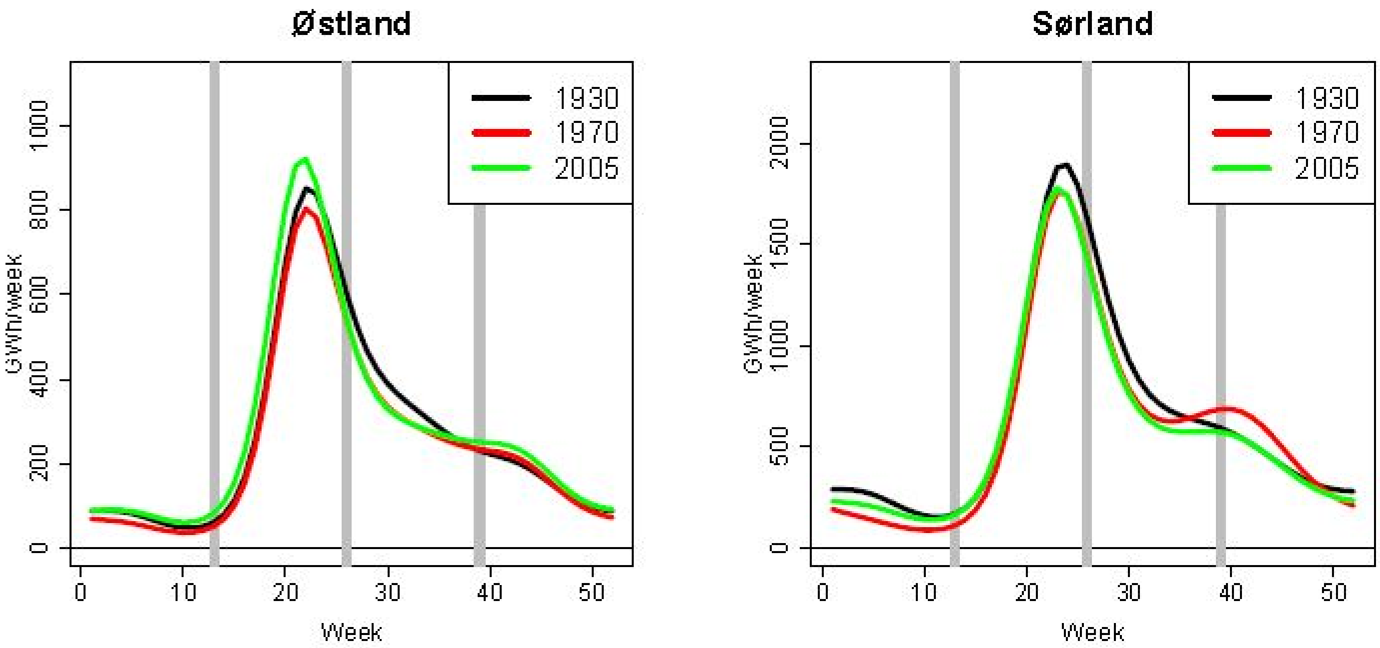
It is modelled as a AR1 model with time dependent "memory" and variance.

The model has a large number of parameters, estimation can be time consuming

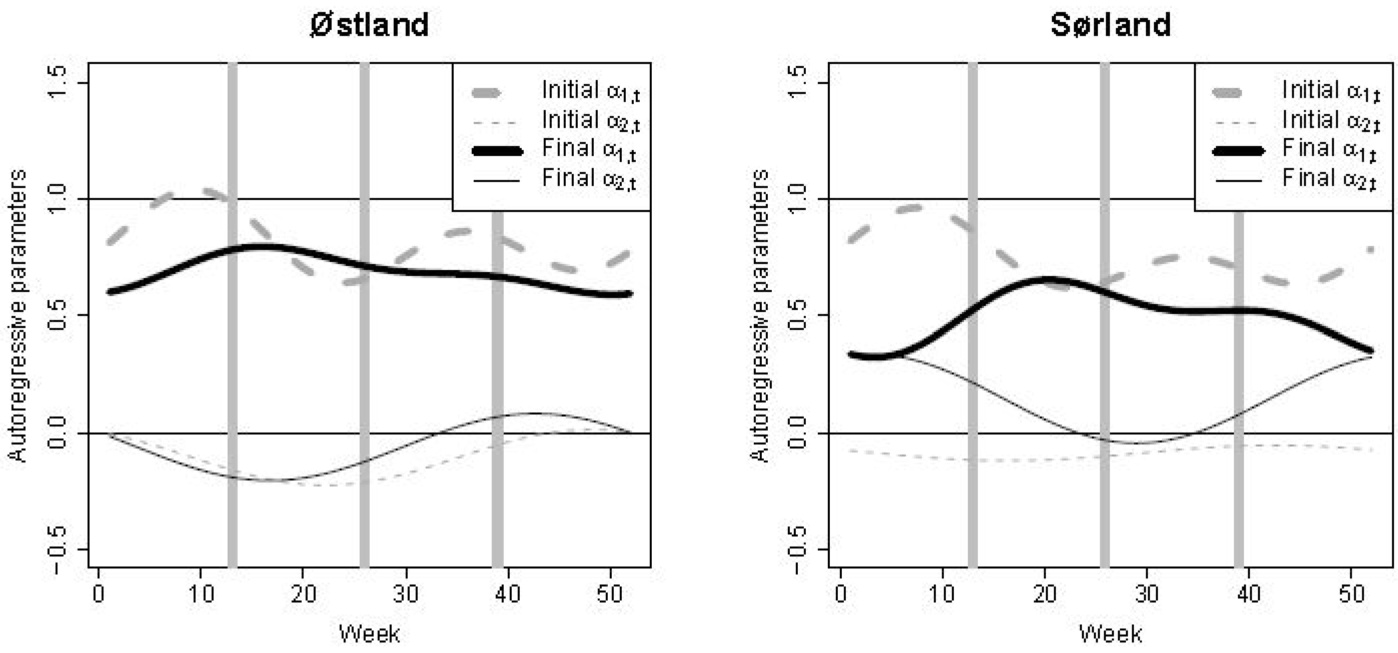
# Fitting Univariate model: Slowly varying mean



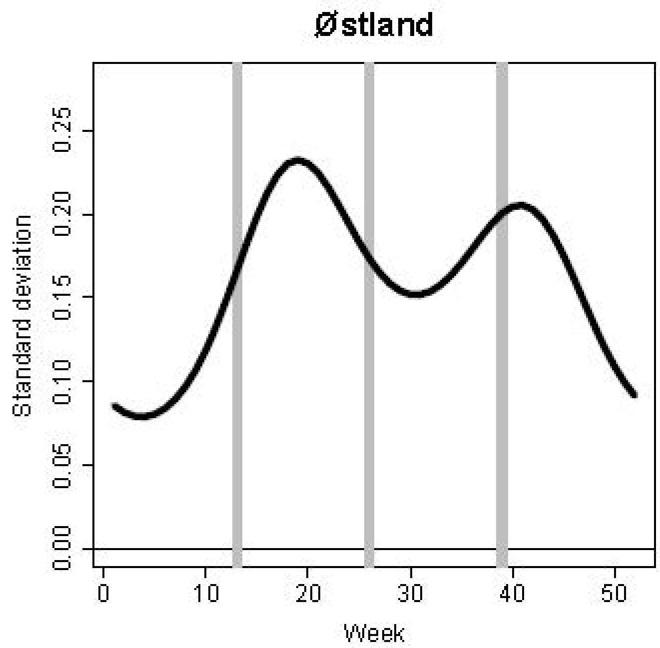
# Fitting Univariate model: Seasonal Component

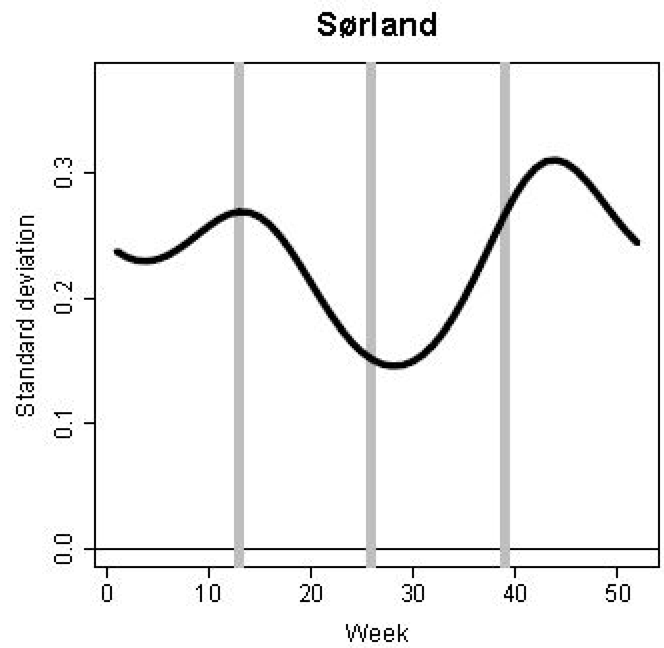


# Fitting Univariate Model: Time varying AR1 paramenters



# Fitting Univariate Model: Time varying innovation standard deviation



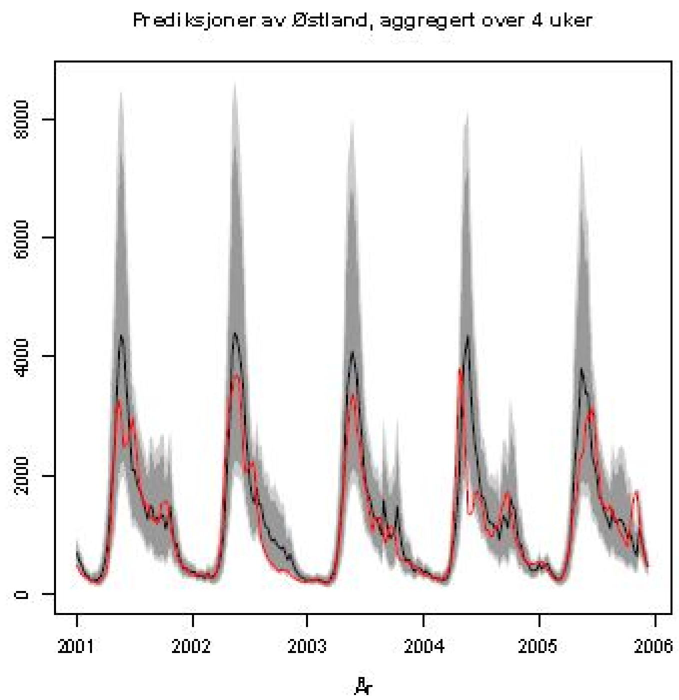
# Model Validation I

# Predicted vs Observed Inflow

## We wanted how good the model is at predicting inflow

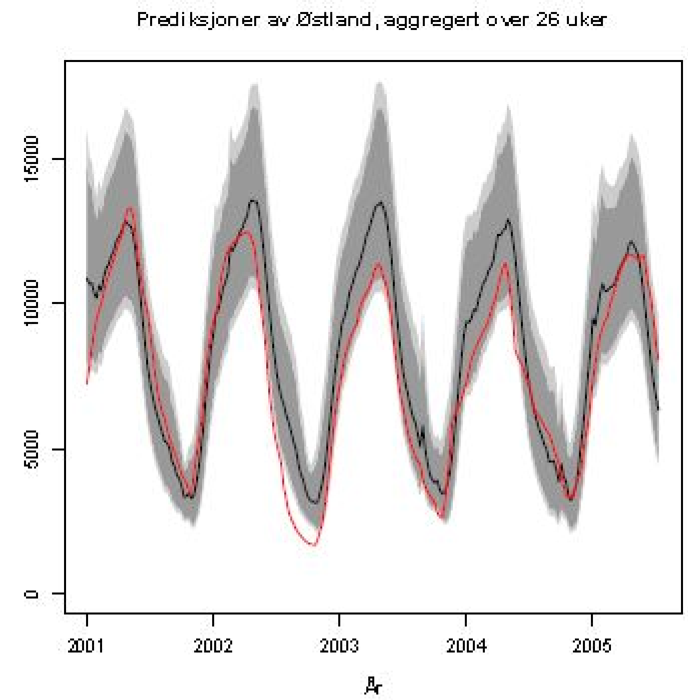
- For each year between 1959 and 2010 we have fitted the model and predicted inflow for the following year
- We have then compared the model predictions with observed inflow for the same year
- We focus on accumulated inflow over 4, 13 and 26 weeks

# Model Validation I: 4 weeks accumulation




Observed Inflow, Mean Predicted Inflow, 90% Confidence Interval

# Model Validation I: 26 weeks accumulation



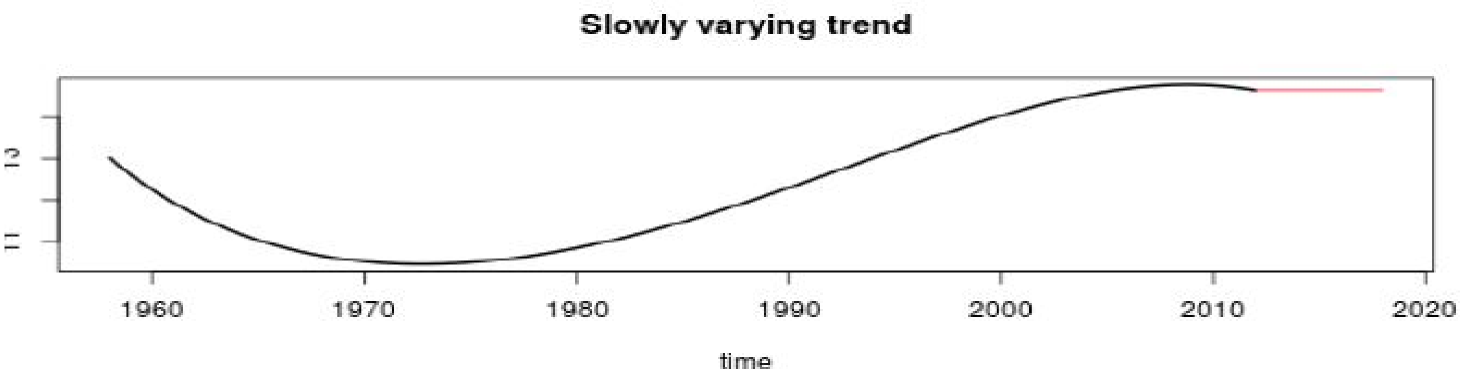

Observed Inflow, Mean Predicted Inflow, 90% Confidence Interval

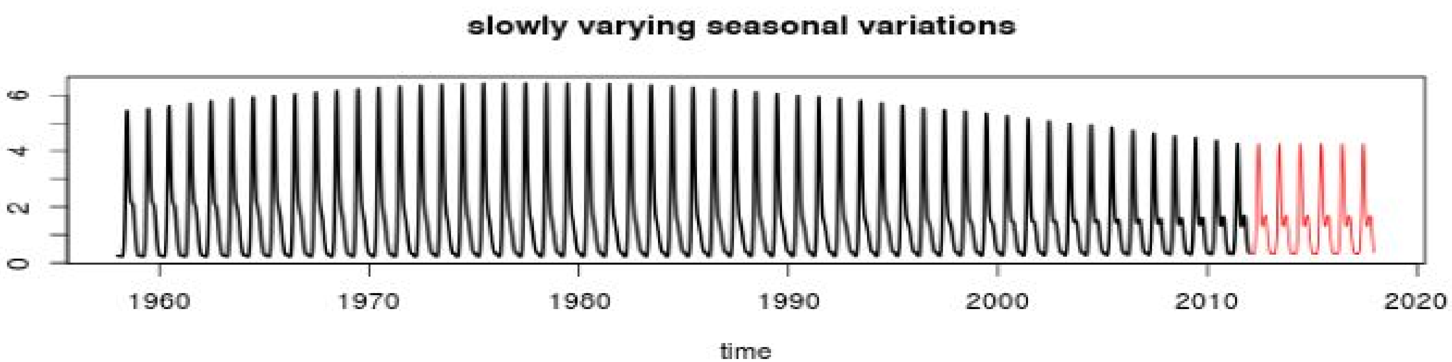
# Model Validation II

## EOPS results, simulated vs observed inflow series

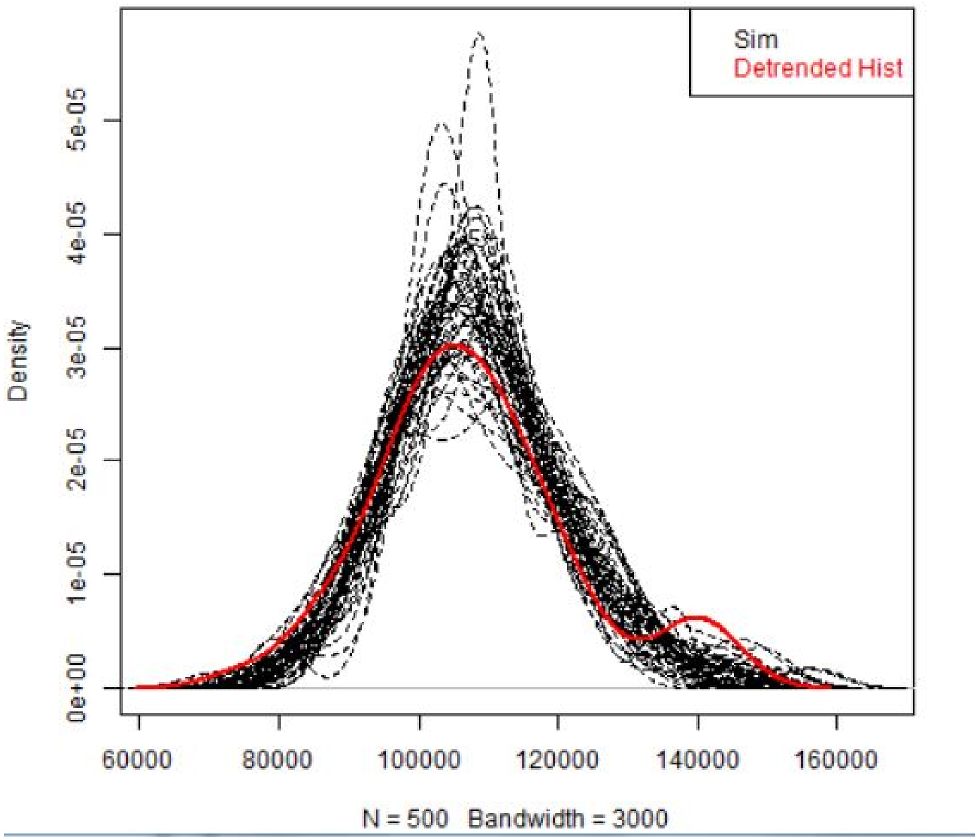
We used the model (fitted over all available data) to simulate new inflow series

Then compare the results of EOPS when fed with the original and the simulated series



# Model Validation II




Density of total yearly inflow

Observed Inflow Series
60 Simulated Inflow Series

# Conclusion

- Have developed a new parametric inflow model
  - Include climate change trends( earlier spring flood, higher average)
- Individual series good at forecasts a few moths ahead (This is also the estimation criteria)
  - Good results for short accumulation periods (4 weeks), less powerful when cumulating over longer time
- Probability of dry periods too small especially when accumulating many series
  - Need to better capture the multivariate structure
  - The result depends on the type of "de-trending" of the observed inflow series