

# Short to Long range Ensemble Inflow Predictions Project (SLEIP)

Presenter: Kim Robinson

# Presentation Overview



- Hydrologic forecasting at Hydro
- The problem
- SLEIP
  - Short Term Forecasting
  - Outlook Forecasting
  - Operationalisation

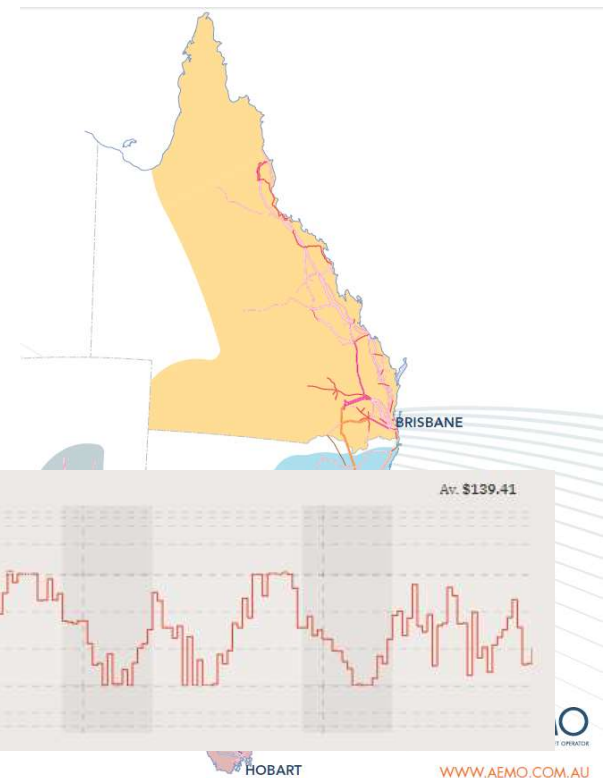


# Why – Commercial stakeholder



## Inform daily power station operation

- Keep the lights on.
- Maximise revenue from each mega litre.
- Avoid spill.
- Operate in a volatile electricity market where spot prices can vary from -\$1,000 to \$15,000 megawatt hour.



# Why – Assets & Infrastructure stakeholders



- Dam Safety: Provide forewarning of flood loading on major dams.
- Forecasting to manage construction flood risk
  - 24/7 forecasting system to enable safe construction during a dam upgrades.
- Best practise hydrology is part of being a responsible dam owner.

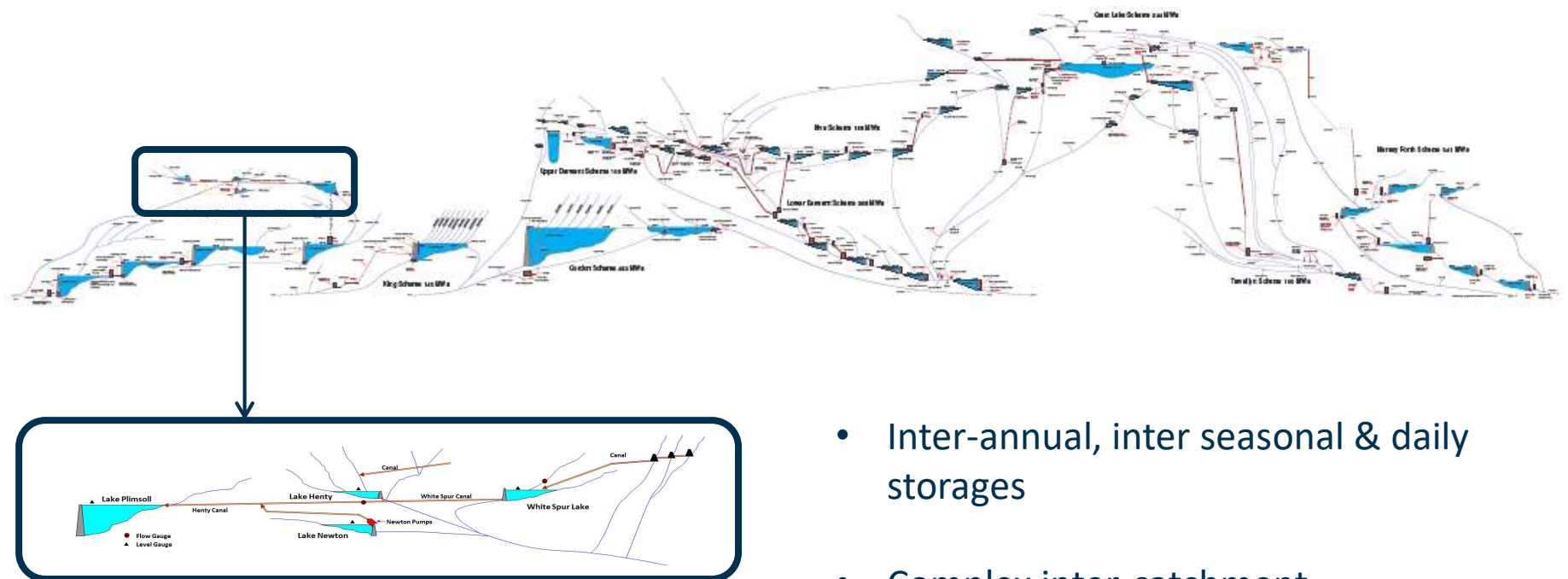


(2015) Engineers Australia





# Hydro System



- Inter-annual, inter seasonal & daily storages
- Complex inter-catchment infrastructure

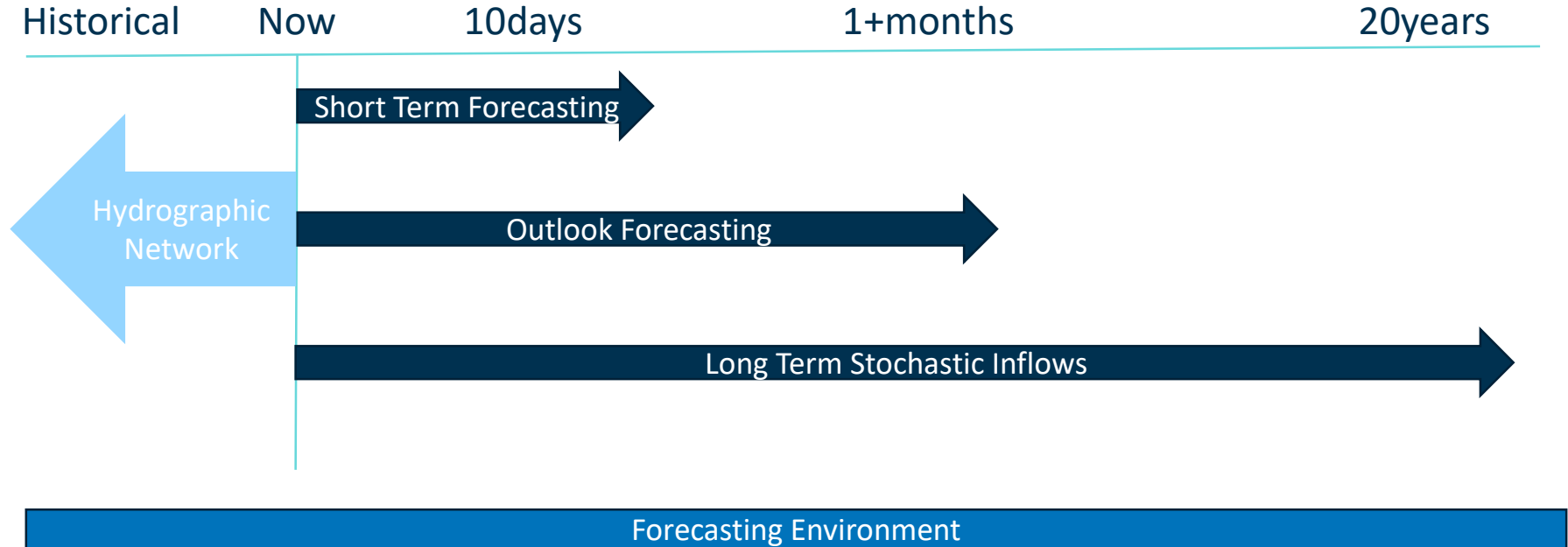
# The Problem



- Very good deterministic forecasts cannot support a risk-based decision making framework and are difficult to assess against other variables (price, likelihood of spill, etc).
- After day 7 we need a better predictor of the future than climatology based on stochastic sampling of historical inflows.

# The Solution (part of)

## Short – Long Range Ensemble Inflow Predictions

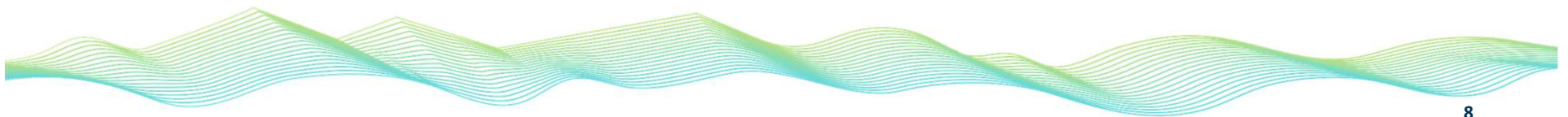


# Overview

## What is being developed



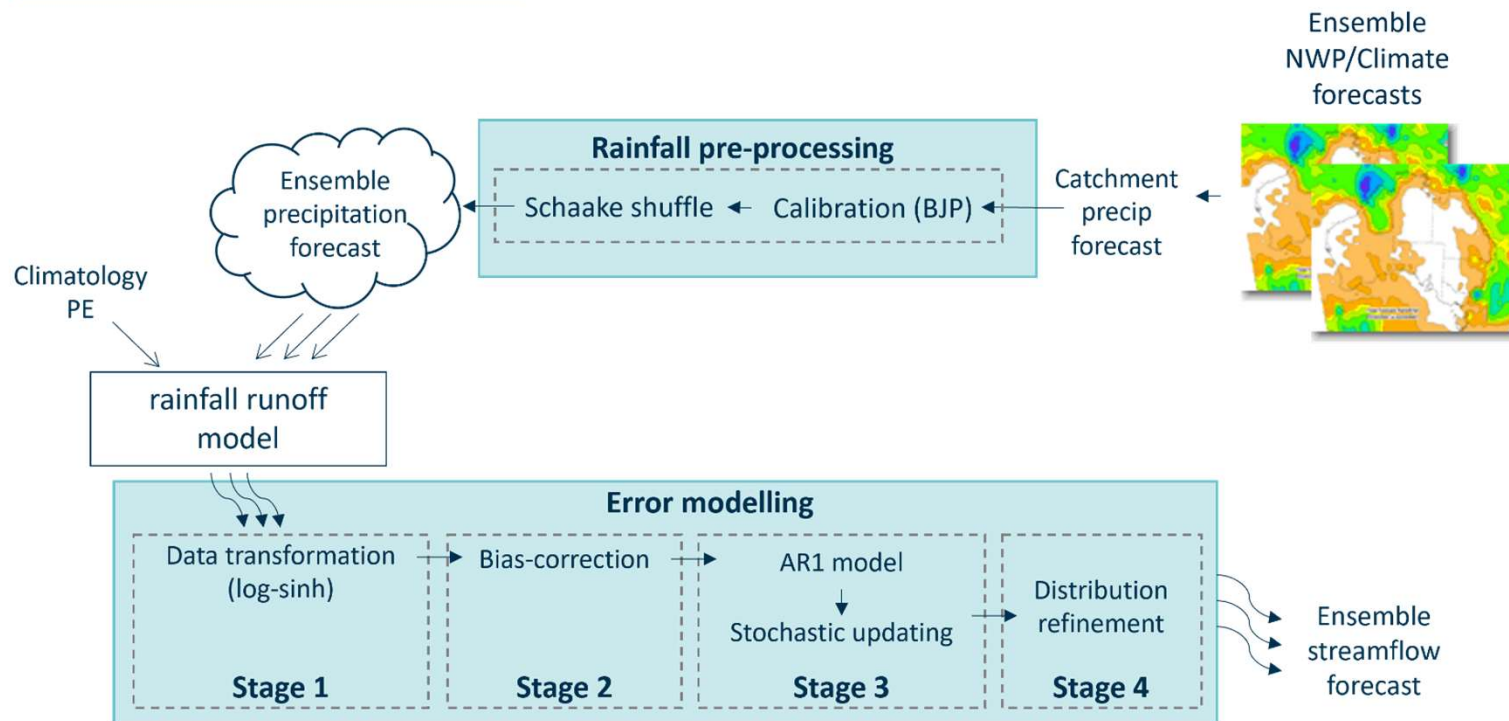
<i>System</i>	<i>Current</i>	<i>Future</i>
Short-term inflows (0-10 days)	<ul style="list-style-type: none"><li>• 7 day best estimate forecast (deterministic forecast)</li></ul>	<ul style="list-style-type: none"><li>• 10 day forecast with uncertainty quantified (ensemble forecasts driven by NWP)</li></ul>
Outlook inflows (1+ months)	<ul style="list-style-type: none"><li>• Random resampling of historical inflows</li></ul>	<ul style="list-style-type: none"><li>• 1+ months forecast with uncertainty quantified (ensemble forecasts driven by climate model)</li></ul>
Long-term inflows (20 years)		<ul style="list-style-type: none"><li>• Stochastic inflow sequence with historical and future trends, uncertainty, wet/dry sequences and extremes captured.</li></ul>





# Short-Term Forecasting

## Modelling Method - Research Design - Findings

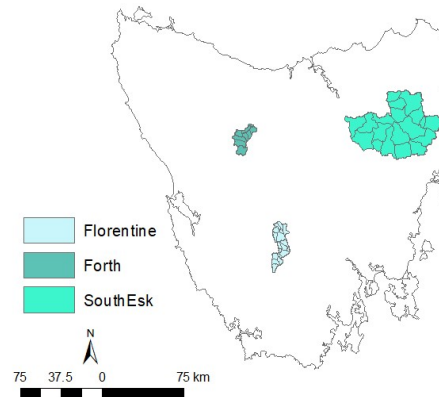


# Short-Term Forecasting

## Modelling Method - Research Design - Findings



- Rainfall forecast analysis
- Rainfall forecast calibration methods
- Rainfall runoff model, routing and error model
- Retrospective forecasts
  - Short-term: Jul 2019 – Jun 2021 (699 forecasts)
  - Strict cross-validation
  - 200 ensemble members
- 7 gauges in 3 catchments

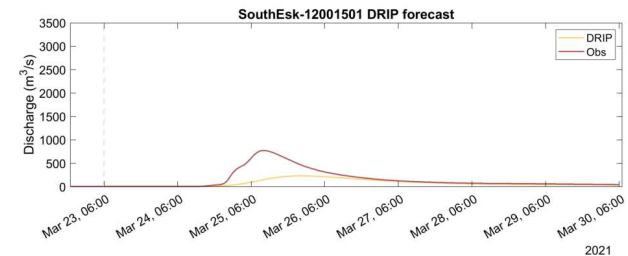
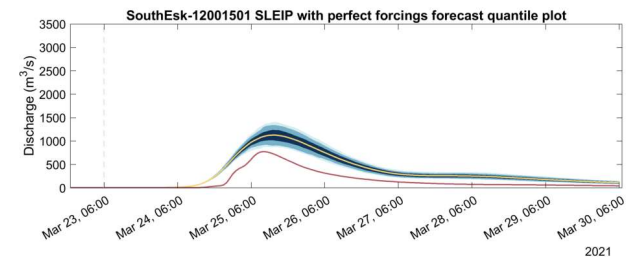
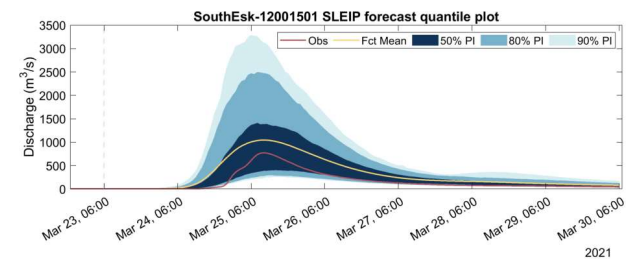
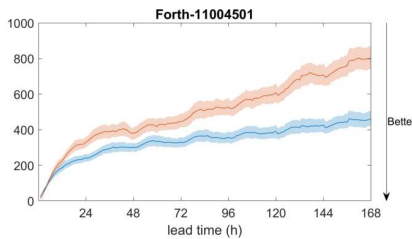
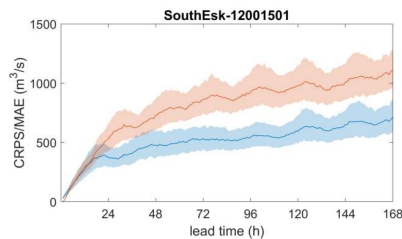
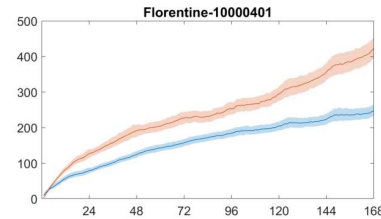
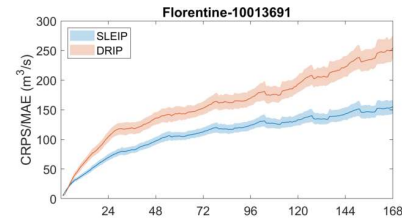


# Short-Term Forecasting

## Modelling Method - Research Design - Findings

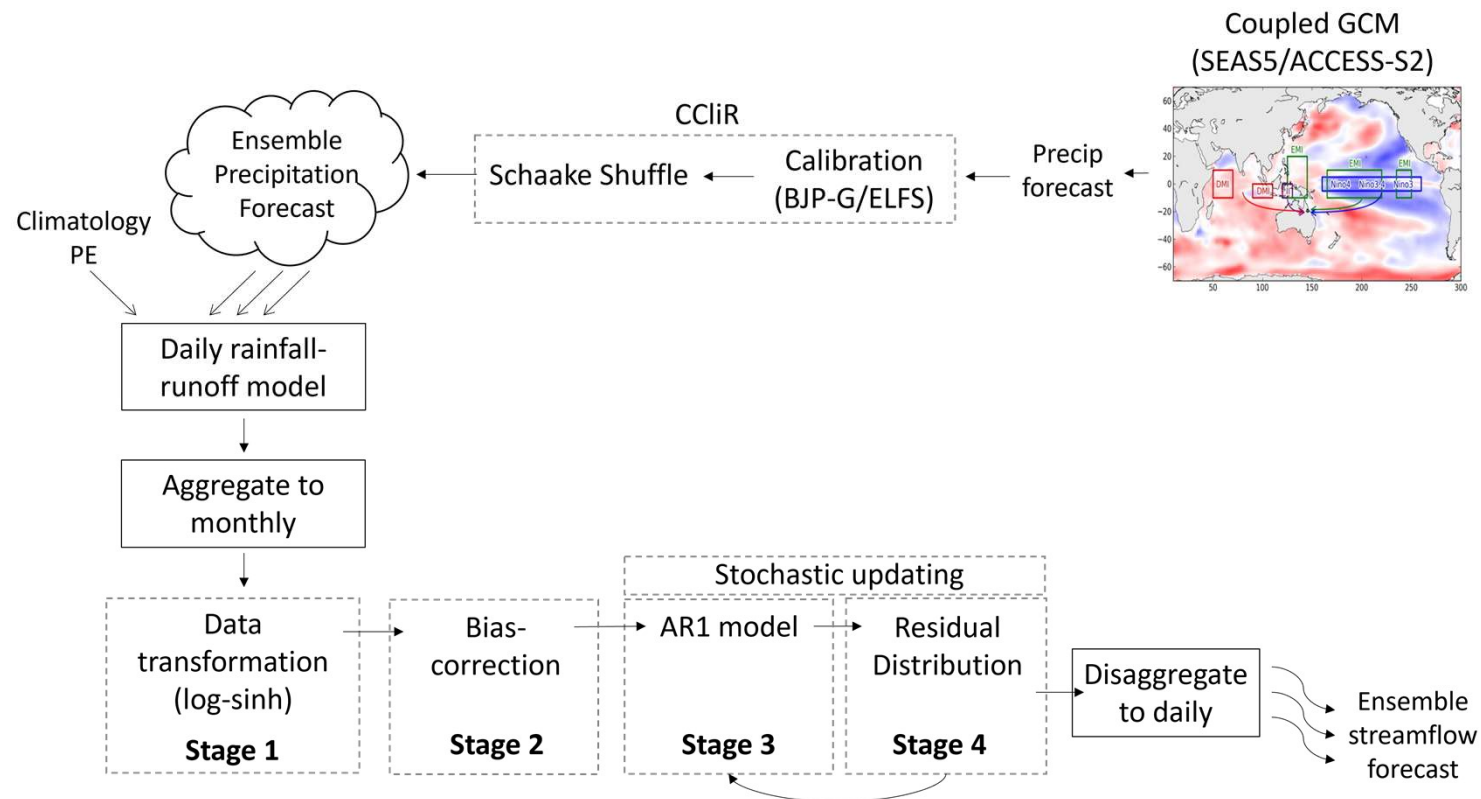


Forecasting methods demonstrated to have equivalent or better performance than the existing deterministic forecast with the additional benefits of quantifying uncertainty, better prediction of peak flows, and extending to 10 days.



# Outlook Forecasting

## Modelling Method - Research Design - Findings

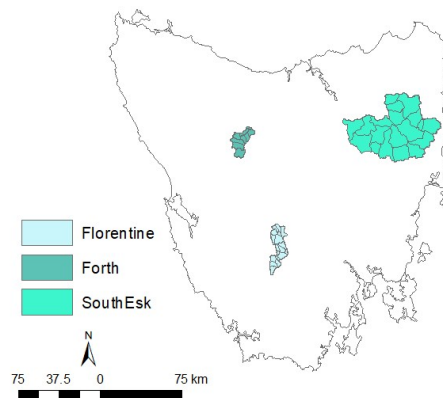


# Outlook Forecasting

Modelling Method - Research Design - Findings



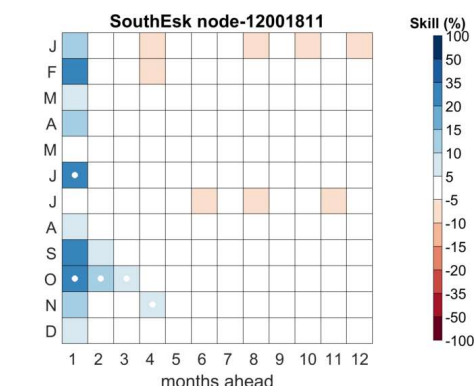
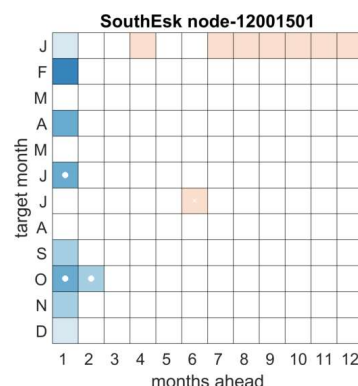
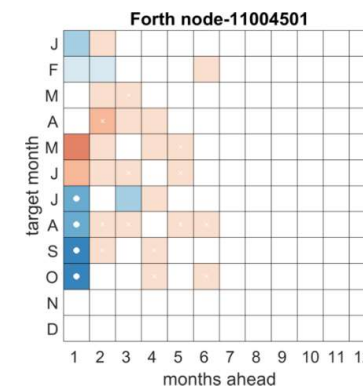
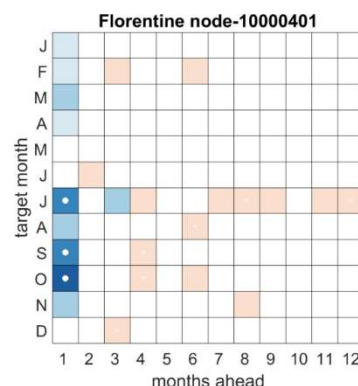
- Rainfall forecast analysis
- Rainfall forecast calibration methods
- Retrospective forecasts
  - Outlooks: 1981-2018 (456 forecasts)
  - Strict cross-validation
  - 200 ensemble members
- 4 gauges in 3 catchments



# Outlook Forecasting

## Modelling Method - Research Design - Findings

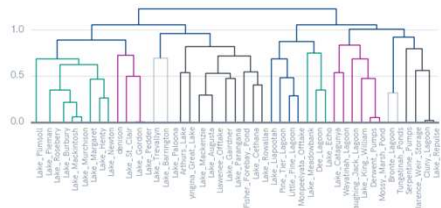
- Skilful (climatology) to 1-month in some seasons
- Accumulations can be skillful to 2 months or more
- Reliable
- Sharpness only ok
- Biases mostly ok, with some underestimation in dry months in South Esk





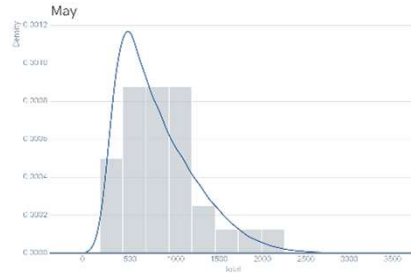
# Long-term modelling

## Methodology

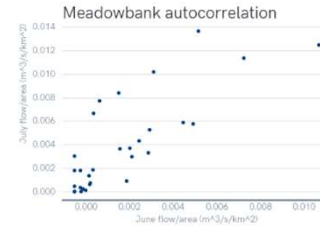


## Spatial correlations

## Research still Underway.



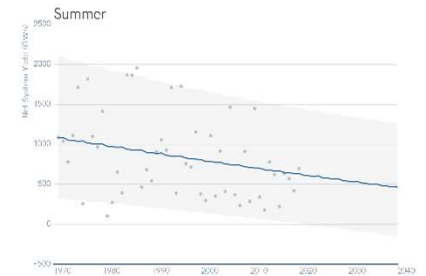
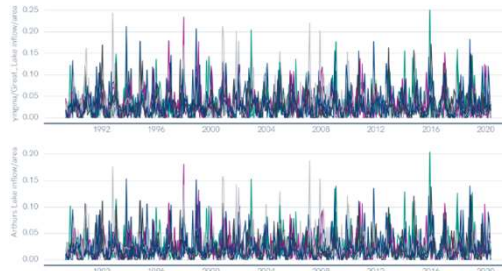
# Bayesian Inference



## Time correlation

$$\mu = \sum_{k=0}^2 \mu_{k,0} \sin(t) + \mu_{k,0} \cos(t)$$

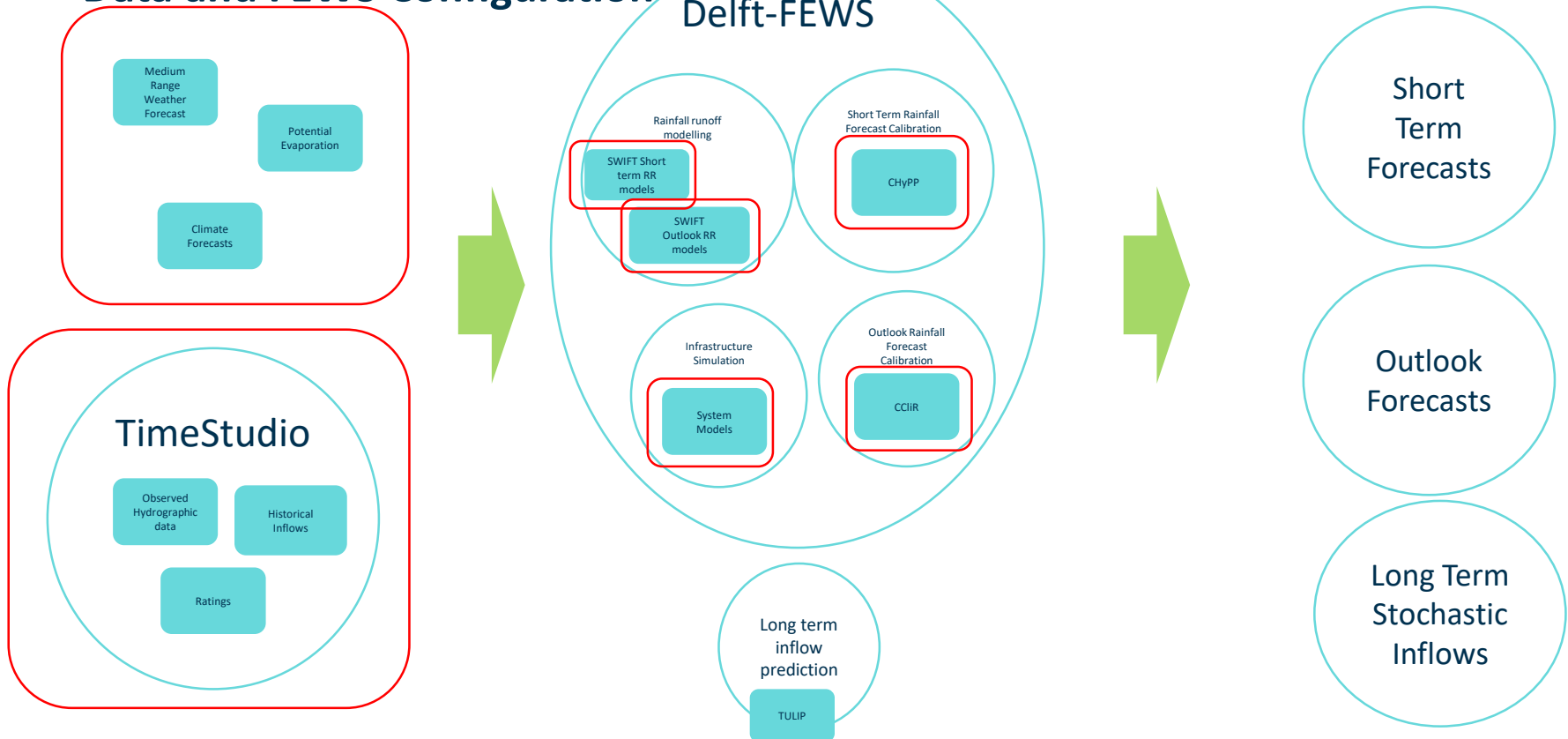
# Fourier Series



## Climate trends

# Operationalisation

## Data and FEWS Configuration

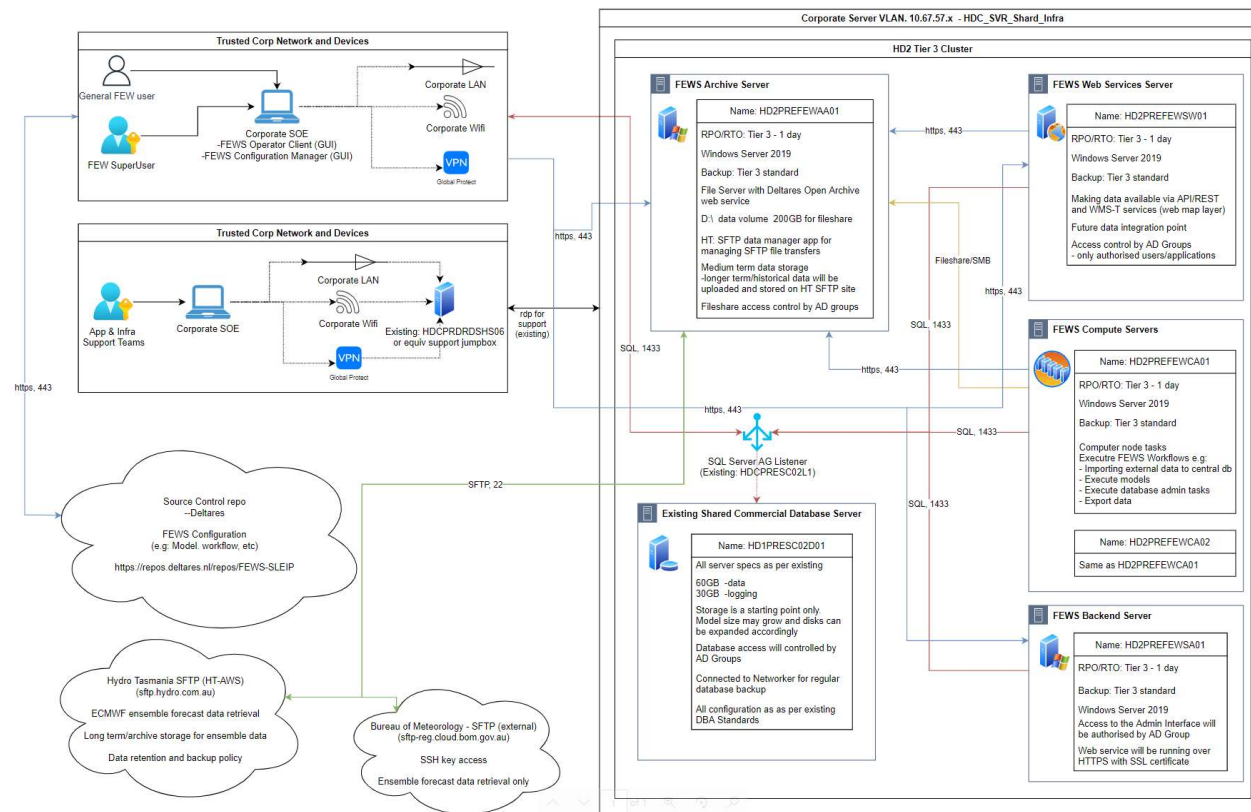


# Operationalisation

## Infrastructure



Delft-FEWS Pre-Production Client-Server Architecture Diagram



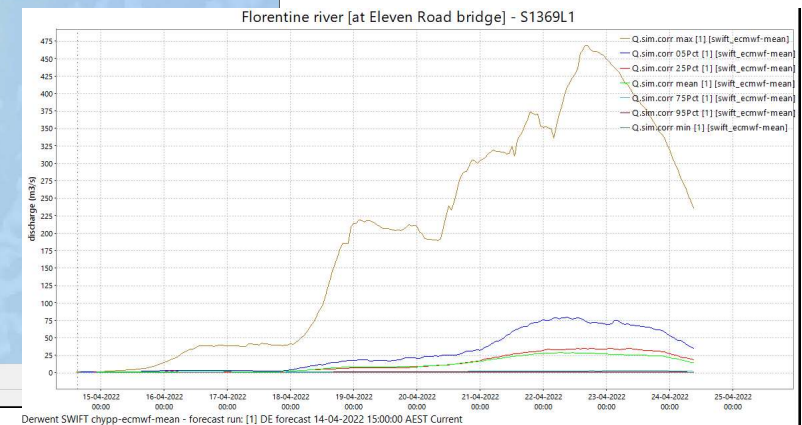
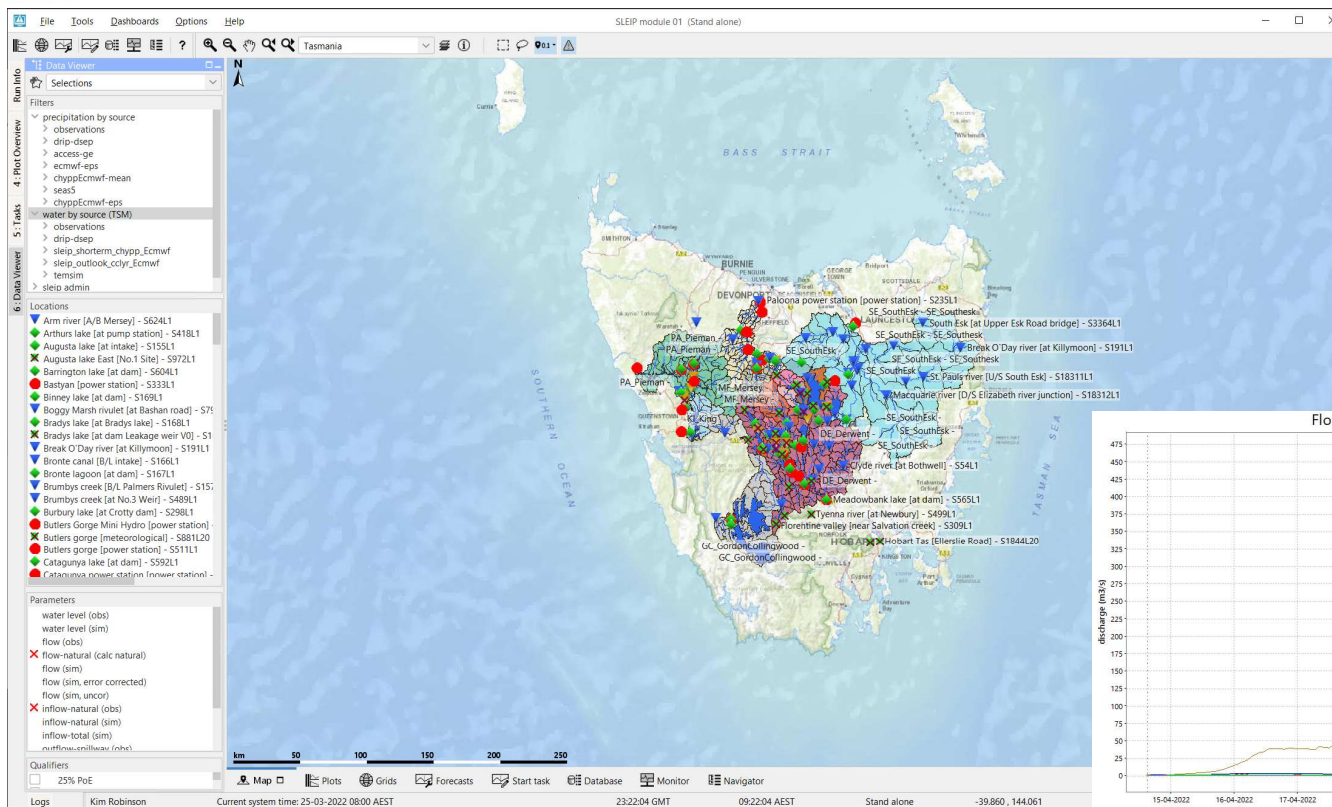
# FEWS Configuration – Work to date



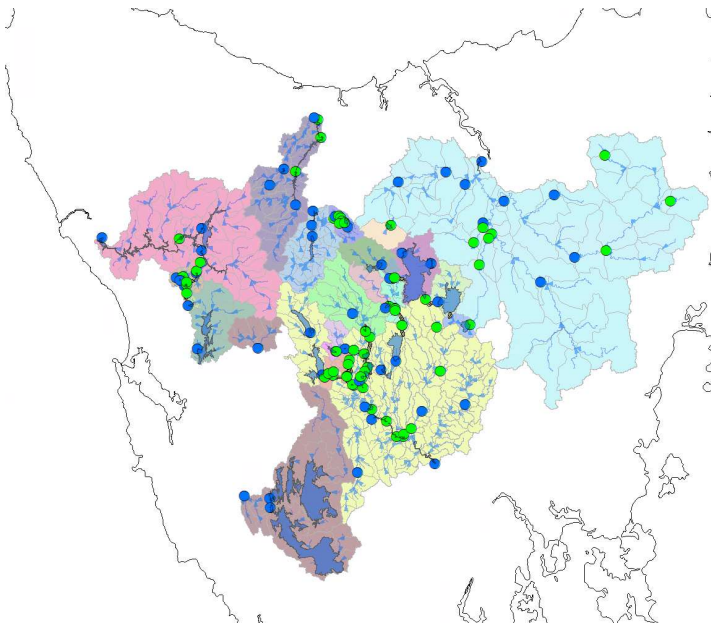
The screenshot displays the FEWS (Forecasting and Evaluation Workbench) software interface. The main window is titled "SLEIP module 01 (Stand alone)". The left sidebar contains a "Tasks" panel with a tree view showing the workflow structure. The "Run Info" panel on the left shows the "Warm state selection" dropdown and the "Time zero: 24-03-2022 22:00:00" and "Forecast length: default" settings. The main workspace displays the "workflows segment ECMWF-mean" workflow, which includes a "Chypp\_Ecmwf-mean\_Forecast" workflow. This workflow is composed of several steps: "updateSoftwareDeltadapters updateSoftwareModel\_Template (GA)", "updateSoftwareChypp updateSoftwareModel\_Template (GA)", "forecaststartProcessEcmwf-eps forecaststartProcessNWP\_template (forecast length estimator)", "chyppEcmwf-meanPreprocess chyppPreprocess\_Template (transformation)", "InterpolationSpatial Average subareas (process)", "StatisticalEnsemble Mean subareas\_mean (process)", "User Simple subareas\_mean\_ens (process)", "forecaststartChyppEcmwf-epsPreprocess forecaststartChyppnwpPreprocess\_template (forecast length estimator)", "chyppEcmwf-meanForecast chyppForecast\_Template (GA)", "idChypp (id map)", "Export timeseries (process)", "rain (sim) (P.sim);subareas (563);chyppEcmwf-epsPreprocess;hour;ECMWF-MEAN (output timeseries)", "Import timeseries (process)", "rain (sim) (P.sim);subareas (563);chyppEcmwf-meanForecast;hour;CHyPP\_ECMWF-MEAN (input timeseries)", "chyppEcmwf-meanPostprocess chyppPostprocess\_Template (transformation)", "Accumulation Sum input (process)", "StatisticalEnsemble Max input\_max (process)", "StatisticalEnsemble PercentileExceedence input\_05Pct (process)", "StatisticalEnsemble PercentileExceedence input\_25Pct (process)", "StatisticalEnsemble Mean input\_mean (process)", "StatisticalEnsemble PercentileExceedence input\_75Pct (process)", "StatisticalEnsemble PercentileExceedence input\_95Pct (process)", and "StatisticalEnsemble Min input\_min (process)". The bottom status bar shows the user "Kim Robinson", the current system time "25-03-2022 08:00 AEST", and the memory usage "884 MB".



# FEWS Configuration – Work to date



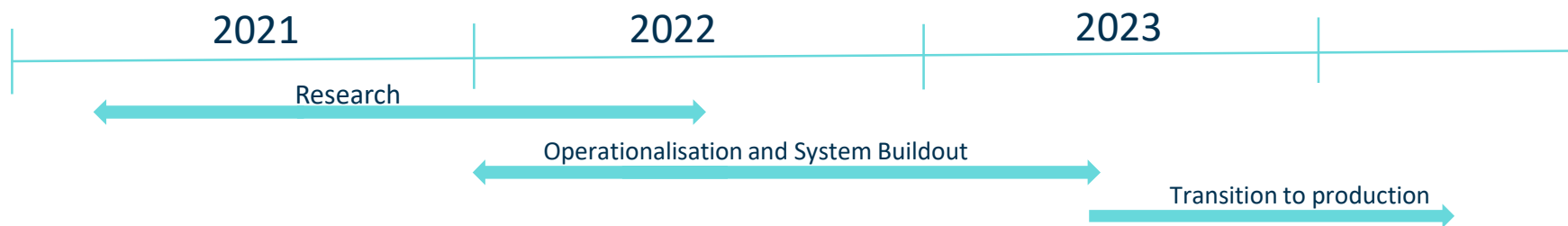
# SLEIP modelling system scale



- Catchment area: 23,000 km<sup>2</sup>
- > 100 forecast points
- >1000 time series feeds from Hydrographic DB
- 3 \* Rainfall forecast ensemble feeds
- 5 \* modelling software packages
- Many models
- Short term and outlook forecasts generated autonomously.
- 500,000 time series generated for each complete update.



# Project timeline and status



# Thank you



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## Acknowledgements

- CSIRO
- WMA Water
- Entura
- Deltares Australia
- Deltares Nederland's