Seasonal Streamflow Forecasting Workshop

Jeff Perkins, Trudy Wilson, Andrew Schepen, Daehyok Shin, QJ Wang and Senlin Zhou
08 November 2011

National Water Information Briefings products in practice
Who should attend

- Water and climate industry professionals and technical staff with an interest in water forecasting and flows. People who would like to influence the design of future Bureau water forecasting products and services.
About the workshop

- Learn how streamflow forecasts are made and where to find current data, along with historical and comparative information
- Learn about the Bureau’s current, experimental and future locations for streamflow forecasting
- Preview the new, dynamical forecasts and methodology that is in development for release
- Join a discussion on how to optimise use of the forecasts and contribute to the development of this service
SSF Workshop

- House keeping
- Wireless networking details ...
- Let's keep it relaxed
- Asks questions whenever you like ... but we may say “we will cover that later so please just hold that thought”
- Speak up if we are going too deep or not deep enough and any issue
Introducing the team

Mrs Trudy Wilson
Mr Andrew Schepen
Dr Senlin Zhou
Dr QJ Wang
Dr Daehyok Shin
Introductions

- What is your name?
- Where do you work?
- What experience do you have with seasonal streamflow forecasting?
- What do you hope to get out of this workshop?
<table>
<thead>
<tr>
<th>Title</th>
<th>Format</th>
<th>Topic</th>
<th>Time</th>
<th>Who</th>
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<tbody>
<tr>
<td>Getting started</td>
<td>Interactive - introductions</td>
<td>Welcome, introductions, agenda and objectives</td>
<td>15 mins</td>
<td>Jeff</td>
</tr>
<tr>
<td></td>
<td>Presentation</td>
<td>Research to operations, product design, user engagement</td>
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<tr>
<td>Understanding probabilistic forecasts</td>
<td>Presentation</td>
<td><strong>Statistical modelling approach and skill scores</strong></td>
<td>15 mins</td>
<td>Andrew</td>
</tr>
<tr>
<td>Product demonstration</td>
<td>Demonstration - follow along with laptops</td>
<td><strong>Using the website and products</strong></td>
<td>20 mins</td>
<td>Trudy</td>
</tr>
<tr>
<td>Exercise</td>
<td>Competitive activity</td>
<td><strong>Who will win the chocolates ?</strong></td>
<td>10 mins</td>
<td>All</td>
</tr>
<tr>
<td>Break</td>
<td>Stretch Legs</td>
<td>Eat chocolates</td>
<td>5 mins</td>
<td>All</td>
</tr>
</tbody>
</table>
# Agenda – second session

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Future directions</td>
<td>Presentation</td>
<td>Where are we heading? Dynamic modelling ... Integrated or blended modelling ... Reference stations ...</td>
<td>10 mins</td>
<td>Jeff/ Daehyok</td>
</tr>
</tbody>
</table>
| User session – influence    | Group activity – white boards – reporting back | Two questions:  
  - Where in your business could you use skilful and reliable seasonal forecasts products and services?  
  - What improvements or new products are needed to increase use? | 40 mins | All          |
| Wrap up                     | Discussion and questions    | Sign up to receive monthly emails Future case studies?                | 10 mins | Jeff         |
Objectives

- you become more familiar with our service and products
- we become more familiar with your user needs
- we get a better understanding of how you make decisions and how we could work with you to incorporate our forecasts in the decision making process
- explore interest in working with us in some user case studies
Operational Seasonal Streamflow Forecasts

- Started December 2010
- Target catchments in Murray-Darling basin and NSW and VIC
  - 36 locations (8 storages)
- Publicly available via Bureau website
- Using CSIRO Bayesian Joint Probability Model
- Zero lead time 3 month forecasts
- Use statistical/dynamic modelling to extend nationally
Stakeholder engagement

- Planning started in January 2009
  - Users, researchers, service providers
- Three workshops
  - Planning and requirements
  - Experimental products
  - Final product design
- Stakeholder meetings with over 20 agencies across Australia
- Experimental website starting December 2009
Built on quality research and science

- Through WIRADA (Water Information Research and Development Alliance):
  - CSIRO’s Statistical Bayesian Joint Probability (BJP) approach
  - Downscaling climate inputs from global climate model to catchment scale for input to hydrological model
  - Dynamic hydrological modelling approach
  - Blending statistical and dynamic modelling forecasts into a single hybrid forecast product
  - Improved climate predictions from the POAMA (Predictive Ocean Atmosphere Model for Australia) seasonal climate forecasts

- BATEA Uncertainty analysis (with Uni. of Newcastle)
Combination of statistical and dynamic modelling

**SKILL**
- Skill of statistical and dynamic is complimentary
- Good skill across more months of the year

**SCALE**
- Can provide forecasts for more sites

**MORE PRODUCTS**
- One month forecasts viable
- Other lead times? Other products?

**FUTURE PROOFING**
- As skill of GCMs improve the skill of SSF improves
• Bureau of Meteorology
  – Extended Hydrological Prediction Section (EHP)
  – Centre for Australian Weather and Climate Research (CAWCR)
• WIRADA Project 4.2 (CSIRO)
• BATEA Stage 1 Project
  – University of Newcastle
  – University of Adelaide
• International collaborations
  – WMO; US National Weather Service; and peer reviews
Thank you...

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National Water Information Briefings products in practice
Understanding probabilistic streamflow forecasts

Andrew Schepen
08 Nov 2011

National Water Information Briefings products in practice
Outline

- Building a statistical model
- Forecasting
- Verification
Building a statistical model

- Forecast three month streamflow and rainfall
- One model per season for each site
- Bayesian approach
  - Captures uncertainty in the relationships between variables
  - Accounts for skewed data containing periods of zero flow
Building a statistical model

• Initial catchment condition predictors
  – Antecedent streamflow and rainfall

• Future climate condition predictors
  – Lagged climate indices
  – El Niño Southern Oscillation (e.g. SOI, NINO34)
  – Indian Ocean (e.g. IOD)

• The predictors are modelled jointly with “future” streamflow and rainfall
Building a statistical model

Predictors
- Q143009
- NINO34

Predictands
- Q143009
- QLD_Brisbane_Gregors_Creek

Months
-2 -1 0 1 2 3
• A probabilistic forecast is produced by conditioning the model with new values of the predictors

• The model can generate an ensemble of any size (say 5000)
Verification

- Quality of forecasts is assessed prior to public release
- All forecast models are cross-validated
  - Forecast each event back in time
  - Use a model built after removing all data about the event
  - Gives an indication predictive performance for future events
- The set of cross-validation forecasts are assessed for accuracy and reliability
Accuracy

- Accuracy is assessed by error scores
- Error = Distance between forecast and observation
  - Root Mean Square Error (RMSE). Measures average magnitude of the errors of point forecast e.g. median
  - Root Mean Square Error in Probability (RMSEP). Like RMSE but penalises conservative forecasts more harshly than extreme forecasts
  - Continuous Ranked Probability Score (CRPS). Takes into account full ensemble/distribution.
Accuracy

- Skill scores indicate forecast value
  - Measure relative improvement over low-skilled model (historical distribution)
  - 0 = no improvement, 100 = perfect forecasting
Reliability

- Most observations should fall in high forecast probability ranges
  - and fewer observations in low forecast probability ranges
Summary

• Information about the catchment state and expected climate are used to forecast three month streamflow totals
• Forecasts are probabilistic
  – 5000 ensemble members
• Accuracy is assessed using error scores
  – skill scores published on website
• Reliability is assessed using graphical plots
Thank you… over to Trudy

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Product and website demonstration

Trudy Wilson
08 November 2011

National Water Information Briefings products in practice
Data boxplot

- **Outliers**: Points outside the whiskers that are defined as
  - Highest value within the range: $(75^{th} \text{ percentile value} + 1.5 \times \text{IQR})$
  - Lowest value within the range: $(25^{th} \text{ percentile value} - 1.5 \times \text{IQR})$

- **25^{th} Percentile**, **Median (50^{th} Percentile)**, **75^{th} Percentile**, and **Interquartile range (IQR)**

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**Image Description**

- **Title**: Achen River at Taggerty
- **Subtitle**: Last twelve months of streamflow
- **Graph Details**:
  - X-axis: Months (Jan to Dec)
  - Y-axis: Monthly streamflow (in mm)
  - Data points indicate streamflow levels for each month.
Thank you...

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Product exercise

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National Water Information Briefings products in practice
For Cairn Curran reservoir how many times in the last 12 months have there been highest ever recorded monthly streamflows?

*twice*
For Kiewa River how many times since February 2011 have there been monthly streamflows recorded below the 25th percentile of the historical record?

once
What is the forecast probability for Dartmouth Dam that a total streamflow volume of 200 gigalitres will be exceeded in the forecast period of July to September 2011?

85%
For July to September 2011 at Dartmouth Dam what is the total streamflow volume that has a 40% forecast probability of being exceeded?

360GL
What is the most likely outcome for this 3 month period - low flow, near median flow or high flow?

Total flow of Ovens River to Murray River
Forecast period: Oct 2011 - Dec 2011

Percentage of forecast in each tercile

- Low flow: 29.4%
- Near median flow: 51.1%
- High flow: 19.5%

Hindcast RMSEP = 37 (Moderate skill)

Near median flow 51.1%
What is the skill score for the January to March forecast for Dohertys in the Goulburn basin?

hindcast RMSEP score 27 (moderate skill)
What is the forecast probability of exceeding the historical average streamflow volume?

18%
Thank you...

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Seasonal Streamflow Forecasting Workshop: Future directions

Jeff Perkins
08 November 2011
BETTER FORECAST FOR MORE SITES!
Outline

- Dynamic seasonal streamflow forecasting
- High Quality Streamflow Reference Stations (HQSRS)
- Roadmap of the national service
8 common catchments with the operational statistical forecasts.
Dynamic Modelling Approach

- Station Data
- AWAP Grid Data
- Observed Catchment Average
- Rainfall Runoff Models calibrated
- Streamflow Outcome
- The same model calibrated with historical data inputs.

- POAMA Forecast Ensembles
- POAMA Downscaled Ensembles
- Forecast Catchment Average
- Rainfall Runoff Models pre-calibrated
- Streamflow Forecast Ensembles
- Posterior Bias Correction
- Dynamic Streamflow Forecast

- 3-monthly Streamflow Forecast updated every month
- Monthly Streamflow Forecast updated every fortnight
Dynamic modelling approach

Modelling system & BATEA

Rainfall runoff models calibrated

Streamflow outcome

The same model calibrated with historical data inputs

POAMA forecast ensembles

POAMA downscaled ensembles

Forecast catchment average

Rainfall runoff models pre-calibrated

Streamflow forecast ensembles

Posterior bias correction

Dynamic streamflow forecast

Station Data

AWAP grid data

Observed catchment average

3-monthly streamflow forecast updated every month

monthly streamflow forecast updated every fortnight
Downscale rainfall forecasts from 270 km to 5 km

POAMA

2.5° × 2.5° (~270km)

Catchment scale

0.05° × 0.05° (~5km)
Dynamic modelling complements statistical modelling.

Skill score categories:
- Low (0-20)
- Moderate (20-40)
- High (>40)
Monthly forecast more accurate than 3-monthly forecast.

Skill score categories:
- Low (0-20)
- Moderate (20-40)
- High (>40)
Guidelines Summary

- High Quality Streamflow Series
- Located in unregulated catchments
- Minimal landuse upstream
A number of stakeholder consulted

<table>
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<tr>
<th>Jurisdiction</th>
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<tbody>
<tr>
<td>New South Wales</td>
<td>New South Wales Office of Water (NOW)</td>
</tr>
<tr>
<td></td>
<td>Sydney Catchment Authority (SCA)</td>
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<tr>
<td>ACT</td>
<td>Actew AGL</td>
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<tr>
<td>Victoria</td>
<td>Department of Sustainability and Environment (DSE)</td>
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<td>Melbourne Water</td>
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<tr>
<td>Queensland</td>
<td>Department of Environment, Resources and Management (DERM)</td>
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<td>South Australia</td>
<td>South Australia Department for Water</td>
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<td>Northern Territory</td>
<td>Northern Territory Natural Resources, Environment, the Arts and Sport (NETRA)</td>
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<tr>
<td>Western Australia</td>
<td>Western Australia Department of Water, Water Corporation</td>
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<tr>
<td>Tasmania</td>
<td>Department of Primary Industries, Parks, Water and Environment</td>
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<tr>
<td>Murray-Darling Basin</td>
<td>Murray-Darling Basin Authority</td>
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<td>Commonwealth Environmental Water Holder</td>
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<tr>
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<td>The Australian Government Department of Sustainability, Environment, Water,</td>
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<td>Populations and Communities (SEWPac).</td>
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Concluding remarks

- Plans underway for an extension of the service (~70 catchments)
- 3-Month forecasts from dynamic approach will complement those from the statistical approach (integrated service)
- Overall, 1-month forecasts showed significantly better accuracy than 3-month forecasts
- A possibility for a new 1-month streamflow forecasting service
- Targeted forecast locations based on scientific criteria and user needs
- Continued to work with research partners and users
Thank you...

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National Water Information Briefings products in practice
Seasonal Streamflow Forecasting Workshop - wrap up

Jeff Perkins, Trudy Wilson, Andrew Schepen, Daehyok Shin, QJ Wang and Senlin Zhou
08 November 2011

National Water Information Briefings products in practice
Statistical Seasonal Streamflow Forecasting system

Model parameters are inferred using Bayesian statistics and Markov Chain Monte Carlo sampling.

Model performance is assessed through cross-validation.

Model predictions are probabilistic, providing a measure of uncertainty and presented as maps, charts and raw data.

Model predictors can include antecedent streamflow, rainfall, climate indicators and other parameters representing soil moisture.
Dynamic modelling approach

The same model calibrated with historical data inputs

Modelling system & BATEA

Rainfall runoff models calibrated

Streamflow outcome

Station Data

AWAP grid data

Observed catchment average

POAMA forecast ensembles

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Dynamic streamflow forecast

3-monthly streamflow forecast updated every month

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Combination of statistical and dynamic modelling

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Next steps and future developments

• Service extension and development
  – Extend to more sites using hybrid dynamic/statistical
    • BJP/POAMA/WAPABA – monthly timestep water balance model
  – June 2012: Pilot monthly and 3-monthly forecasts from daily time step dynamic modelling
  – 2012-2013: Operational forecasts from blended statistical/dynamic
  – Aim to have seamless integration at user/products interface
Next steps and future developments

- Hoping to work with stakeholders to case study:
  - Integrating seasonal forecasts with River Operator and River Manager modelling suite (SourceRivers, eWater CRC) or REALM or IQQM.
  - Improving water allocation announcements in key irrigation basins
  - Enhancing the decision making process for announcing and lifting urban water restrictions
  - Optimising water trading between agencies (rural and urban) and moving water around the Victorian (in south-east Australia) Water Grid
  - Improving management of environmental flows

- Need to understand how users make decisions
Acknowledgement

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• BATEA Stage 1 Project
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• International collaborations
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