FNZC

Observations from a scratch-built CDDP implementation

EPOC Workshop Presentation

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Outline

Based a well established approach, how does our implementation perform?

Motivation & criteria

Hindcast 2010-2016

Sensitivities:

- **Remove risk/conservatism placeholder**
- **Manapouri inflow treatment**
- **Reserves & Kirchoff powerflow**
- **Ignore serial correlation during guideline formation, and no sim heuristics**

Observations & next steps

Source for all charts and tables in this document: FNZC estimates

Motivation & criteria

Sector commentary during a period of change requires hydrology to be modelled

Motivation: why build a hydro-thermal optimisation model?

- **We want to offer forward-looking commentary about sector participants and their investment and operational decisions** in response to risk/opportunities from potential changes (e.g. Tiwai, grid investment, decarbonisation, new storage options, renewable variability, carbon price, Solar PV, new builds etc).
- **Inflow uncertainty & hydro-lake management** are key determinants of NZ electricity spot price dynamics (and hydro-generator offers sit at the spot price margin for roughly 67% to 75% of all trading periods)
- **So such commentary isn't credible/possible without a hydro-thermal model** to take account of efficient lake management and renewable fuel variability

Model criteria:

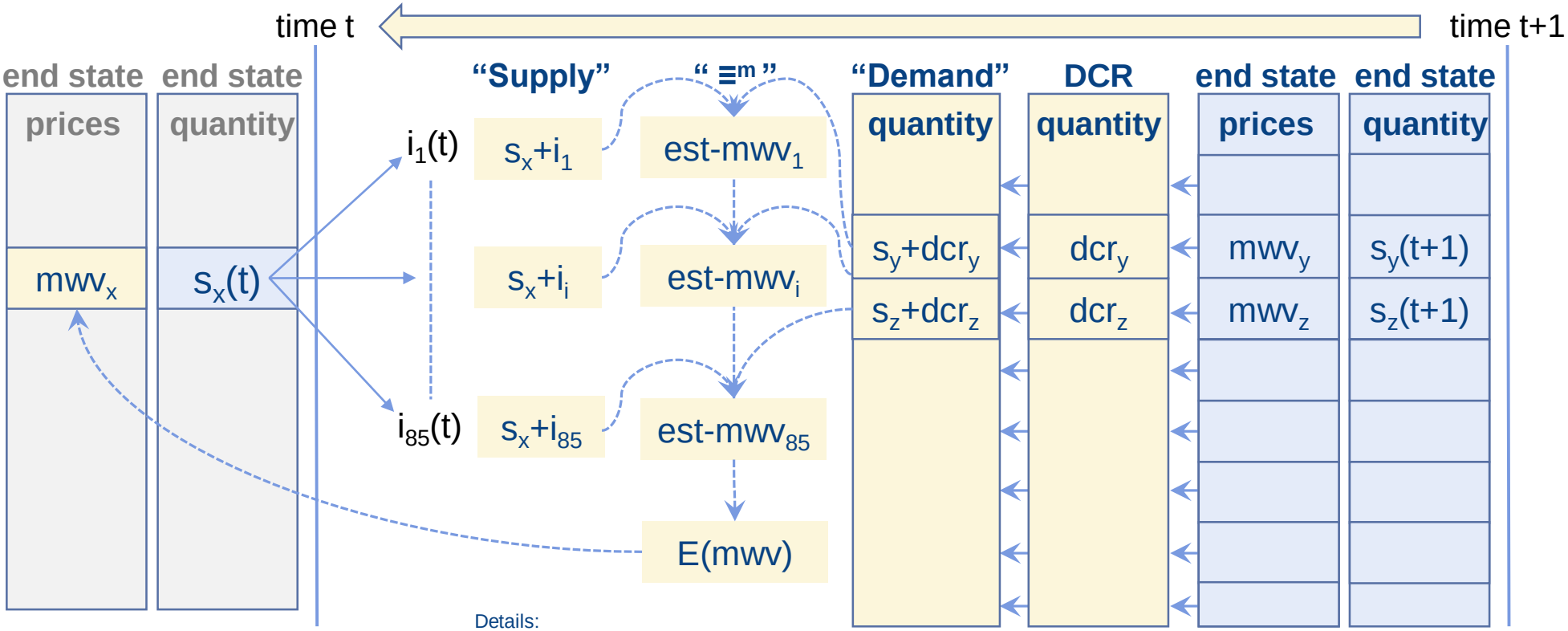
- **Compute time budget** (target: 30-minutes on average PC for 2-reservoir 15-year run [read+opt+sim+trace])
- **Open-source tools only** (Pydata stack, GCC, CLP/CBC)
- **Public data sources only** (HMD, EMI, vSPD GDX file data, POCP, NZX-published financial data)
- **Sufficiently fine-grained to address potential questions** (15-block load, weekly staging, 6-segment piecewise linear losses, HVDC+13 AC-links, 13 regions, 85 inflow years, up to 5 reservoirs, reserves & Kirchoff)
- **Must exhibit decent fit with historical data** (hindcast between 2010-2016)
- **CDDP-based** (Read & Hindsberger 2009) chosen for familiarity, tractability, ease of introspection, speed

Implementation

Vanilla (Stochastic) Constructive Dual Dynamic Programming

Two phase algorithm:

- **Optimisation (backwards recursion to construct water value surface)**
- **Simulation (forwards sim for all known inflow sequences, based on water value surface)**



Nature reveals time=t innovations from distribution

Details:

- Demand response (~460MW) treated as offered generation in 5 tranches ($150-$350/MWh)
- **Interpolation at "edges": $0/MWh for full, $3,300/MWh at empty for each storage**
- Mean trib flows used for guideline formation
- Un-modelled renewable generation output (e.g. wind, small hydro) fixed at actual observed values
- Can choose whether to apply heuristic "spreading" to inflows during optimisation phase
- Manapouri inflows substituted with 3-week M.AVG, after min & cap, and 3-week surplus/deficit bleed

Nature reveals time=t+1 innovations from distribution

Implementation

Vanilla (Stochastic) Constructive Dual Dynamic Programming

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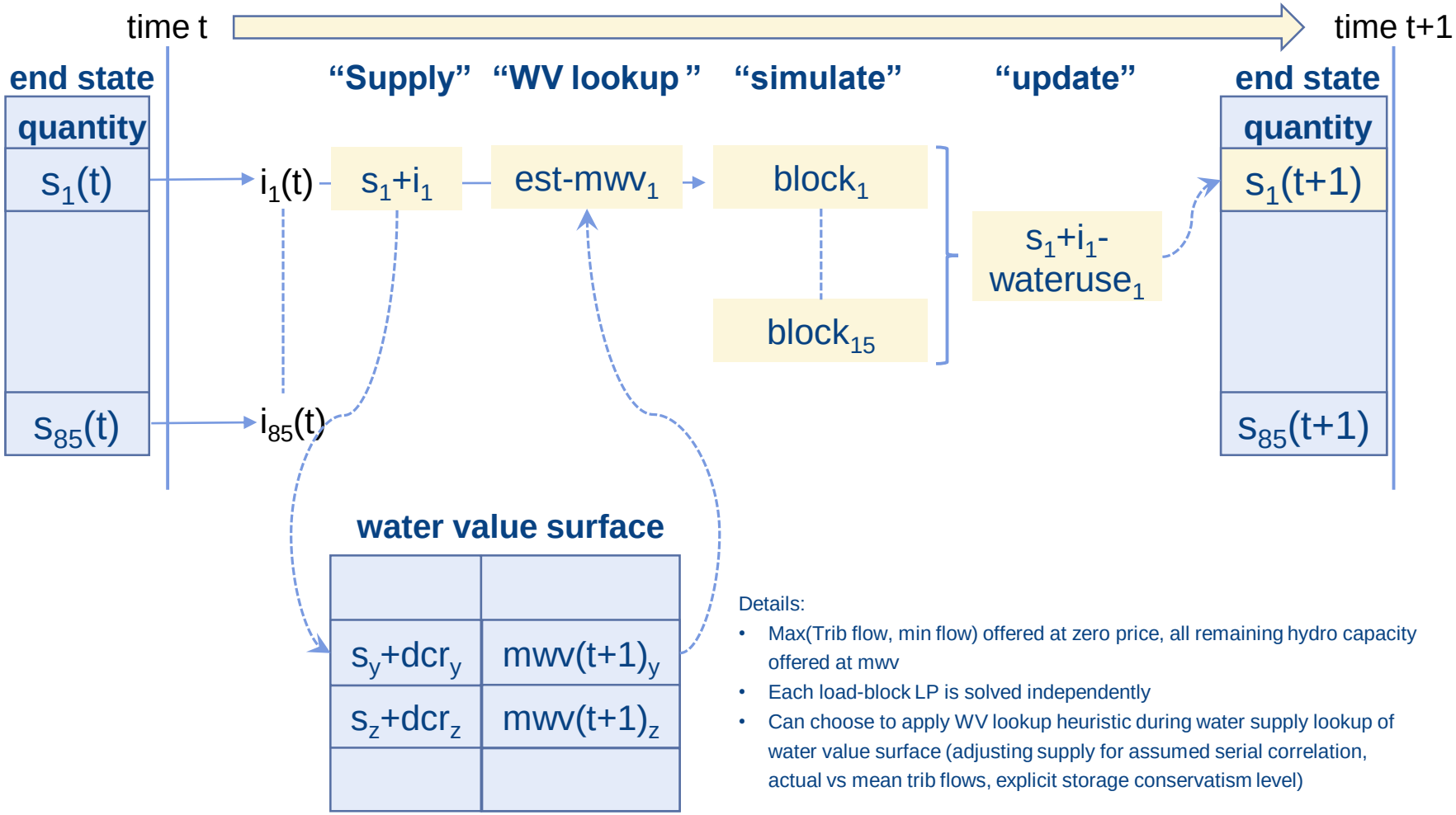


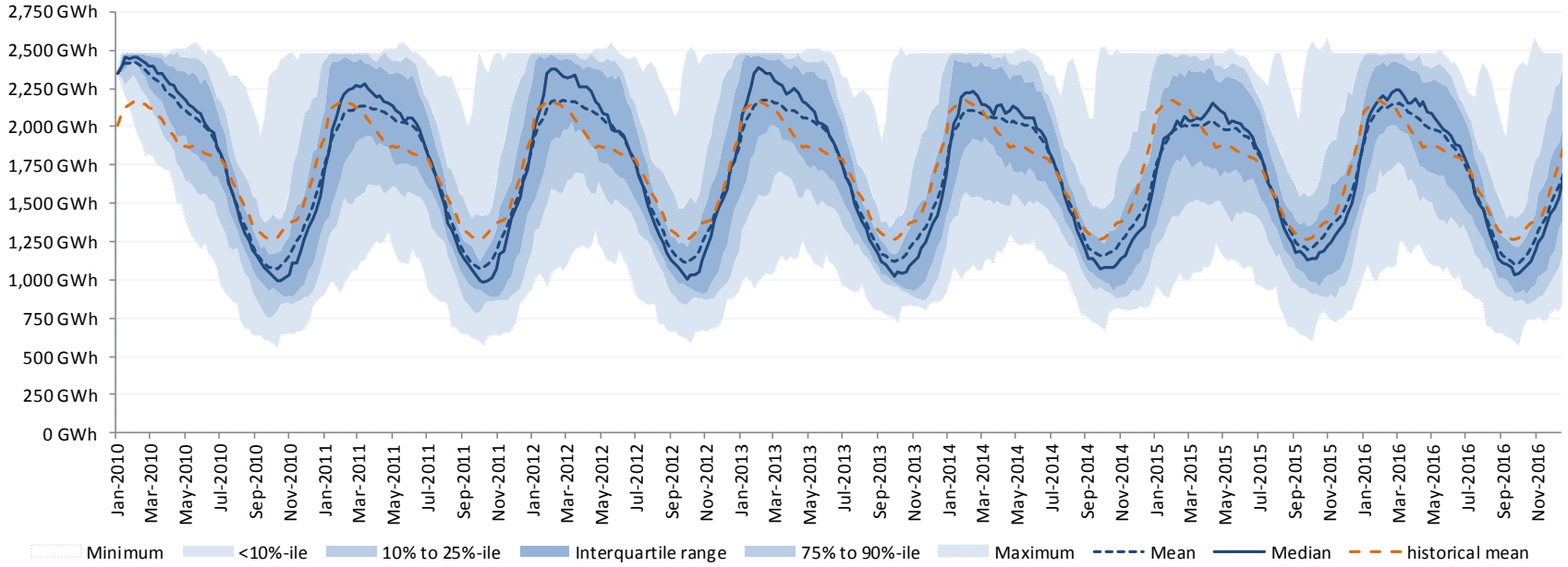
Details:

- Max(Trib flow, min flow) offered at zero price, all remaining hydro capacity offered at mwv
- Each load-block LP is solved independently
- Can choose to apply WV lookup heuristic during water supply lookup of water value surface (adjusting supply for assumed serial correlation, actual vs mean trib flows, explicit storage conservatism level)

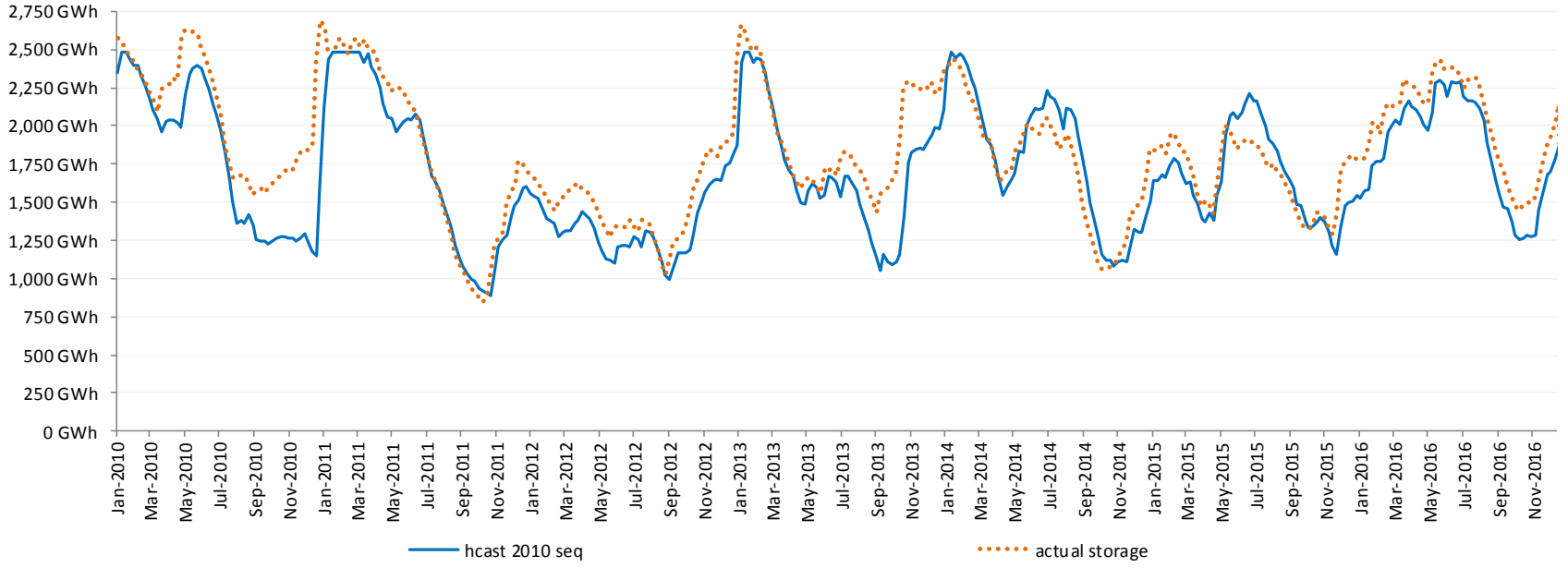
Hindcast 2010-2016: South Island storage traces

Heuristics: 4-week inflow spreading, ρ=0.5, SI 600GWh conservatism placeholder

Pukaki + Tekapo storage sim: all 85 inflow sequences



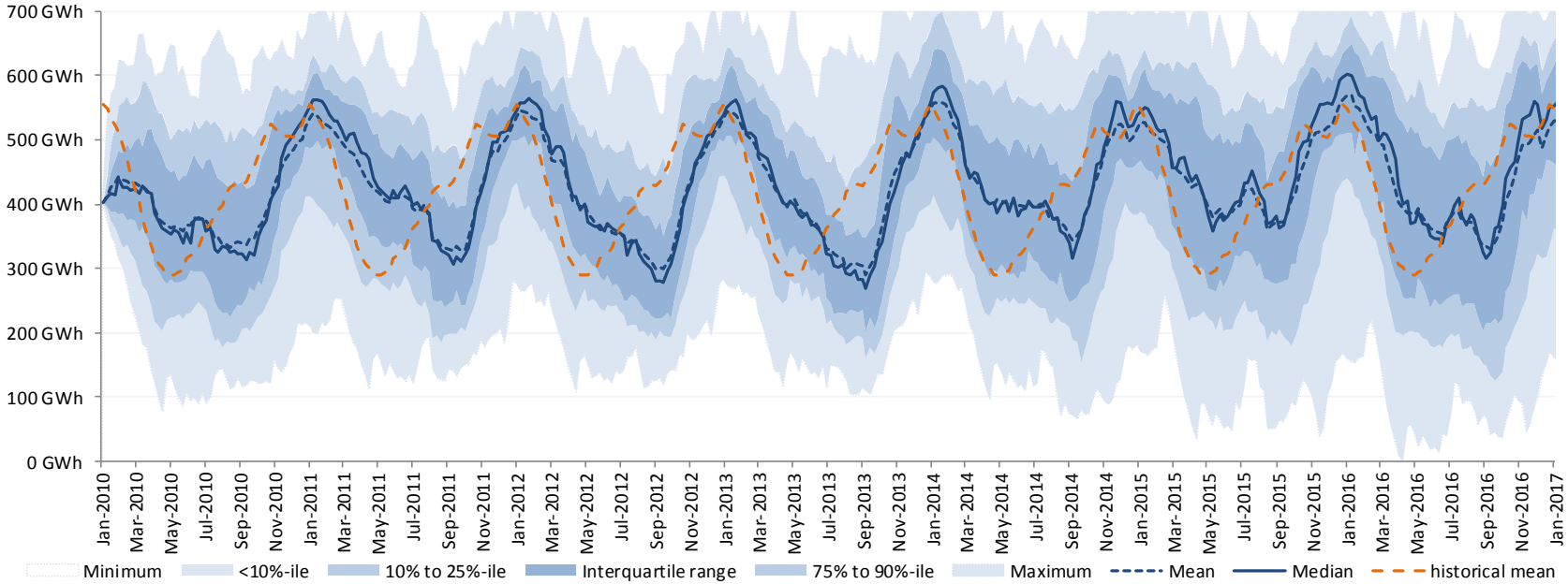
Pukaki + Tekapo storage sim: 2010 inflow sequence



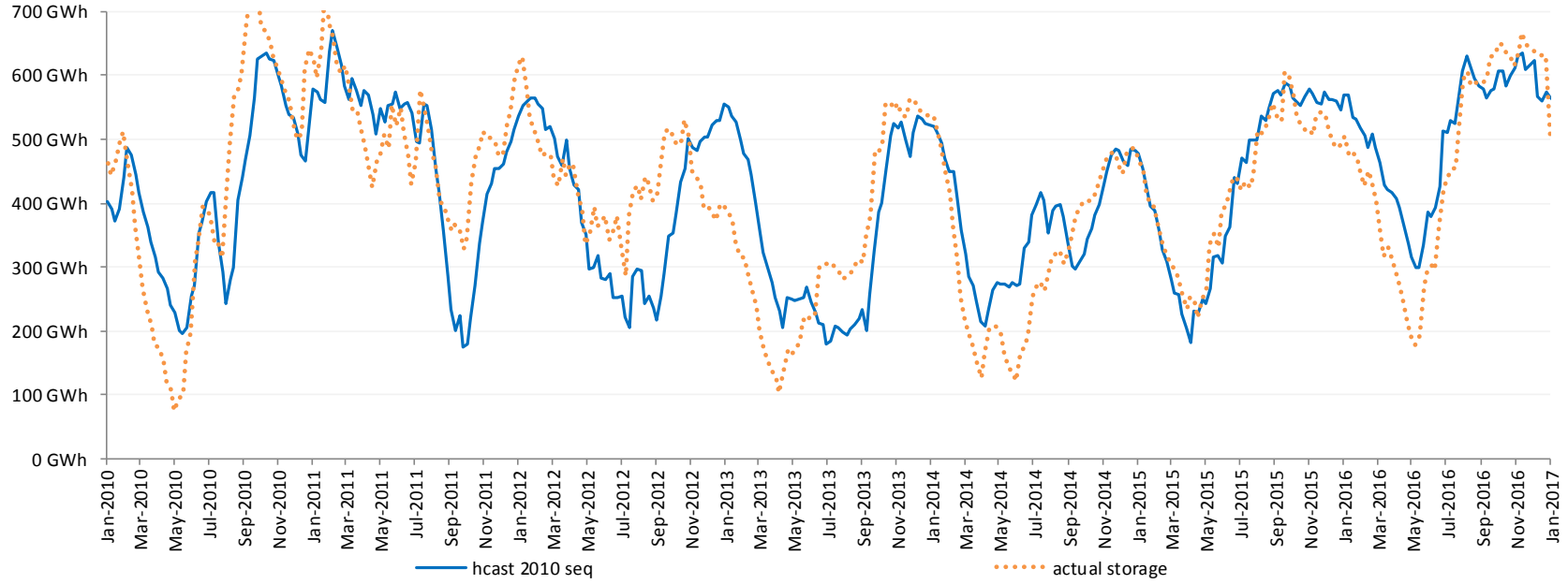
Hindcast 2010-2016: North Island storage traces

Heuristics: 4-week inflow spreading, ρ=0.5, SI 600GWh conservatism placeholder

North Island storage sim: all 85 inflow sequences



North Island storage sim: 2010 inflow sequence

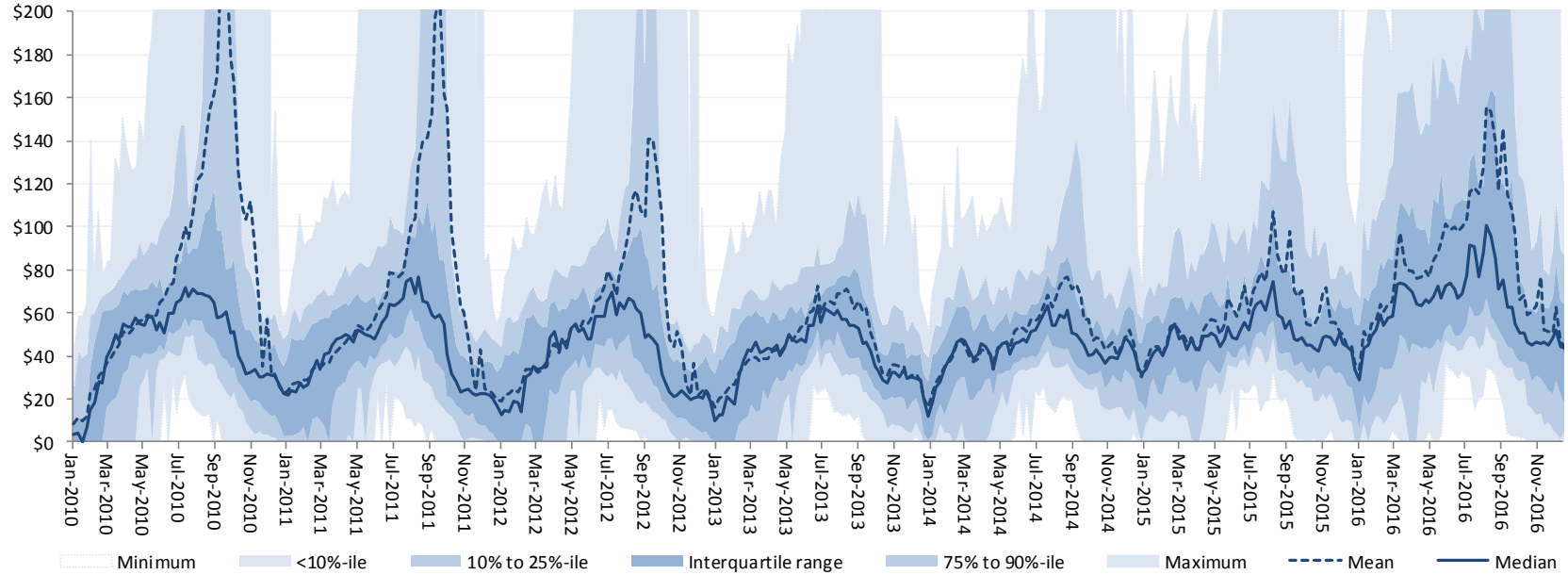


Hindcast 2010-2016: South Island price traces

Heuristics: 4-week inflow spreading, ρ=0.5, SI 600GWh conservatism placeholder

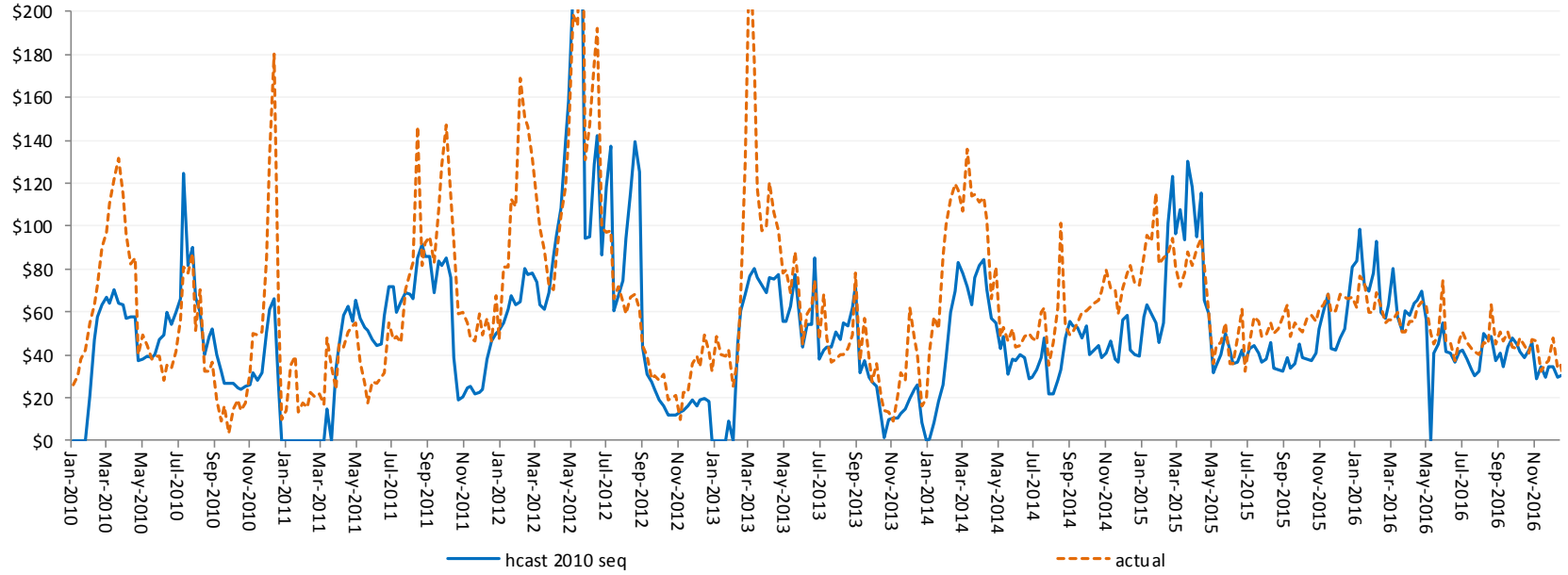
BEN spot price sim $/MWh: all 85 inflow sequences

(mean sim price = $63/MWh)



BEN spot price sim $/MWh: 2010 inflow sequence

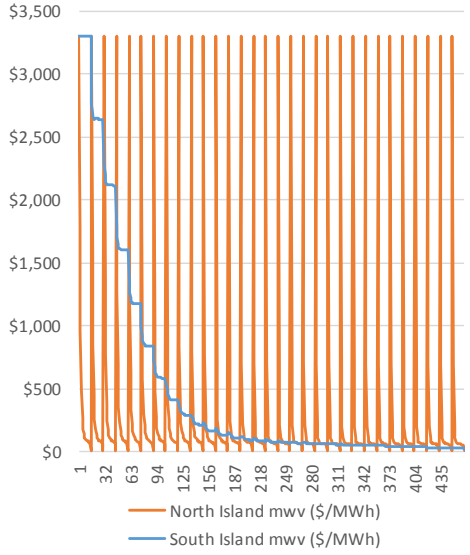
(mean sim price = $51/MWh, actual avg spot = $63/MWh)



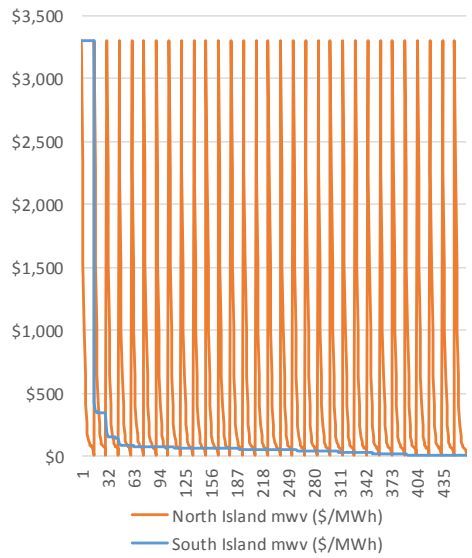
Hindcast 2010-2016: under the hood

Water value surfaces, unserved energy, thermal generation for 2010 inflow sequence

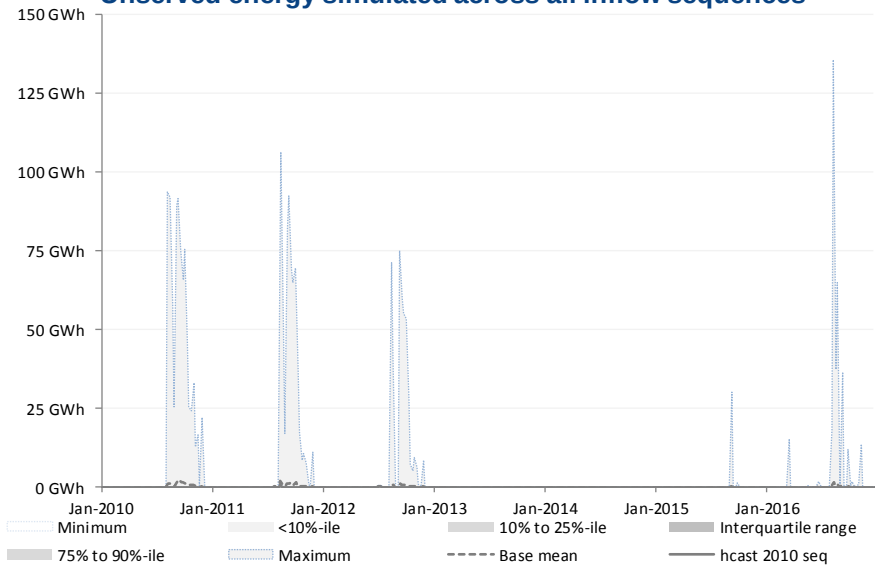
Water value surface – week 26 2010



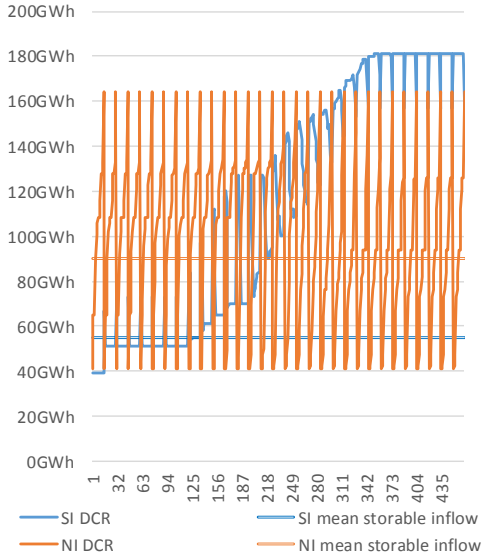
Water value surface – week 52 2010



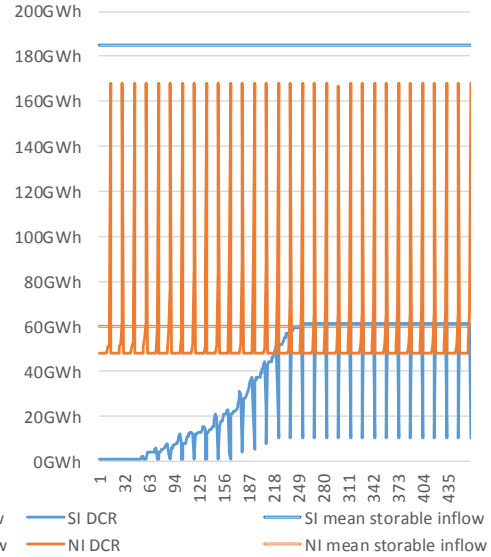
Unserved energy simulated across all inflow sequences



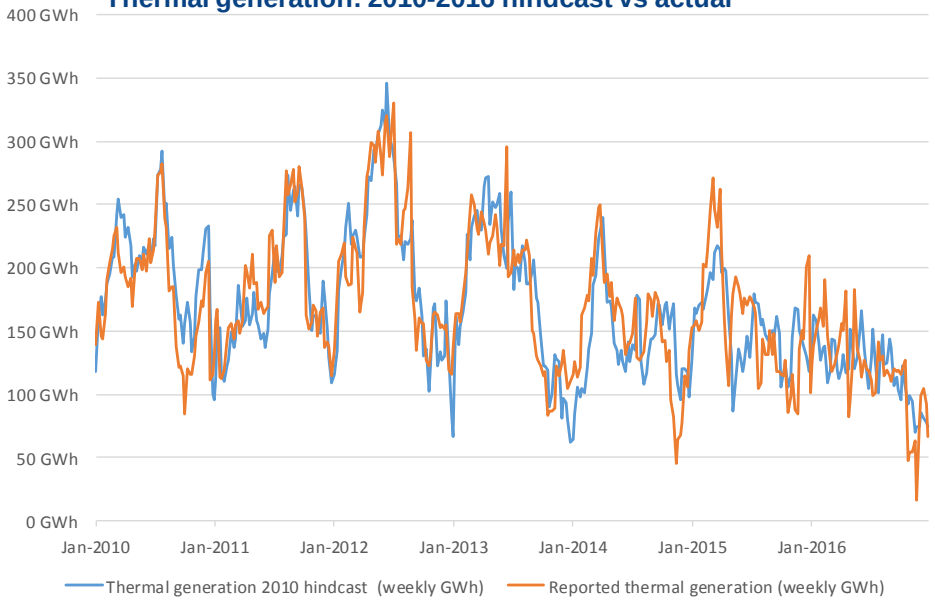
DCR – week 26 2010



DCR – week 52 2010



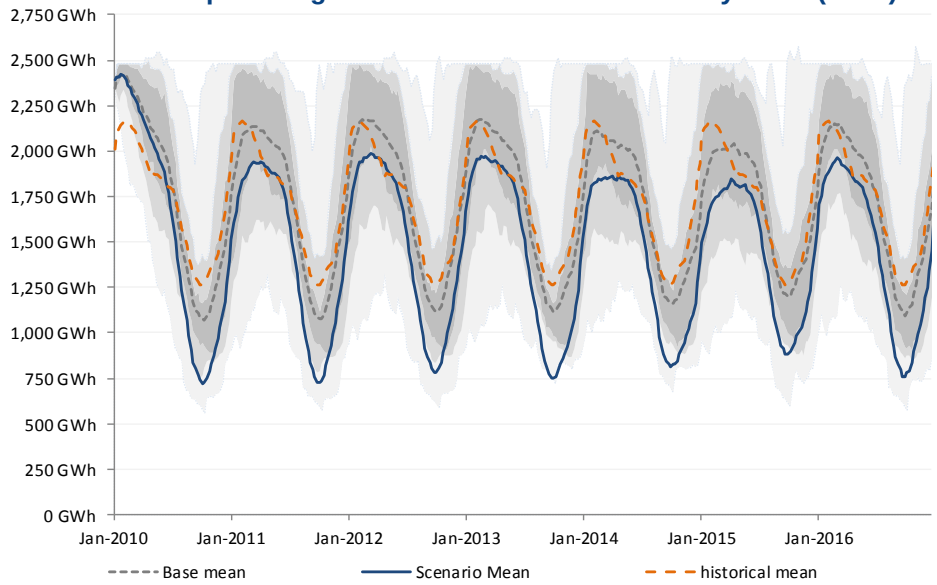
Thermal generation: 2010-2016 hindcast vs actual



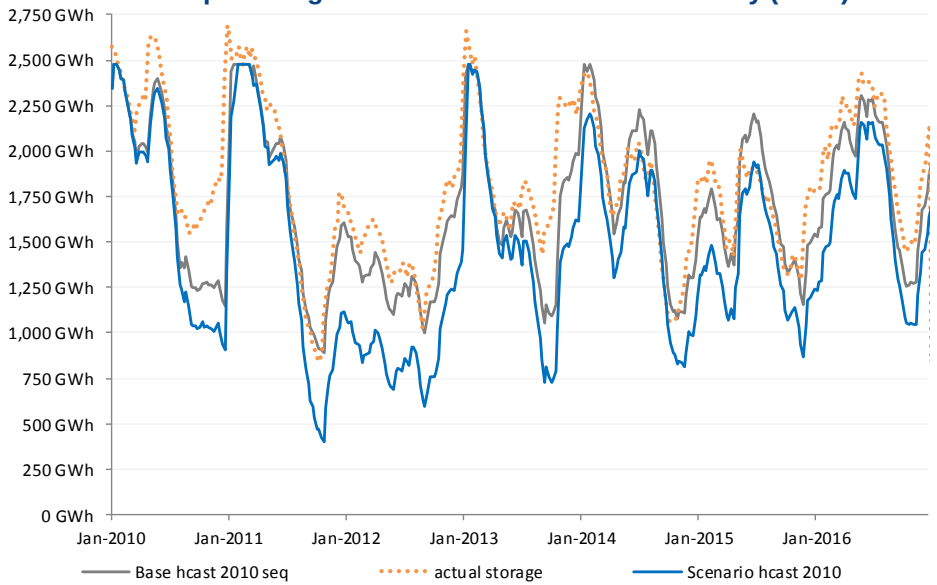
Sensitivity: remove conservatism placeholder

0GWh SI "conservatism" in WV lookup, but retain inflow spreading & other heuristics

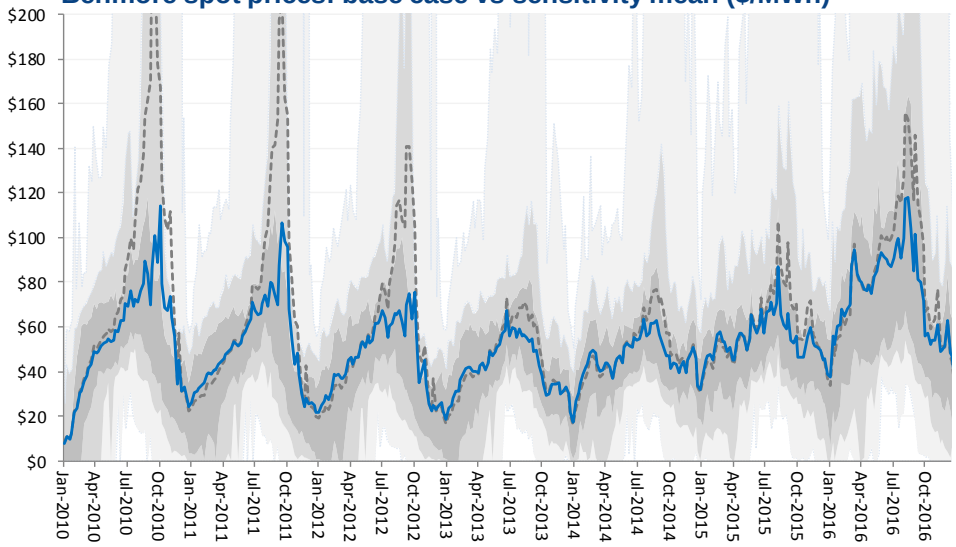
Pukaki+Tekapo storage traces base case vs sensitivity mean (GWh)



Pukaki+Tekapo storage 2010-2016 hindcast vs sensitivity (GWh)



Benmore spot prices: base case vs sensitivity mean ($/MWh)



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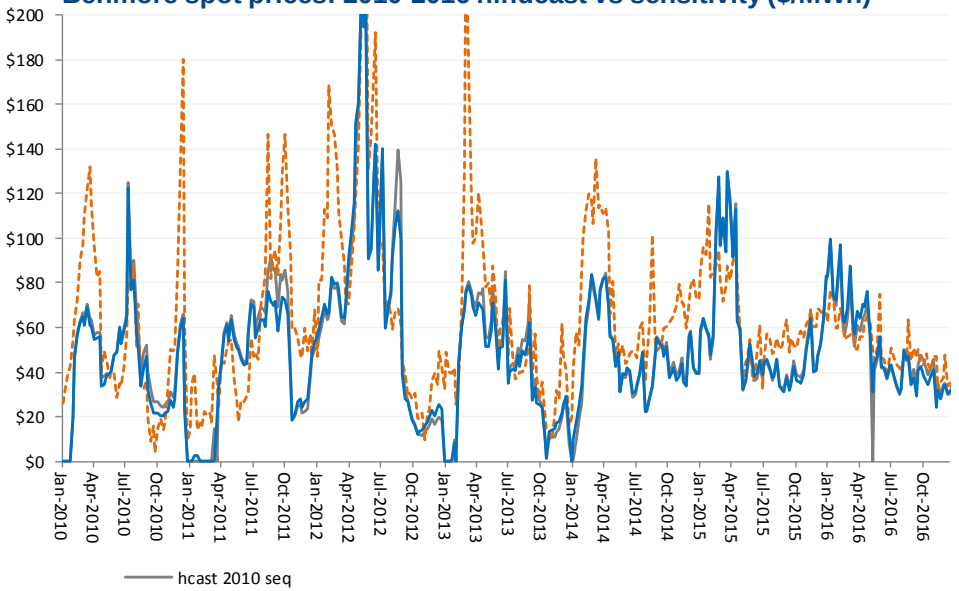
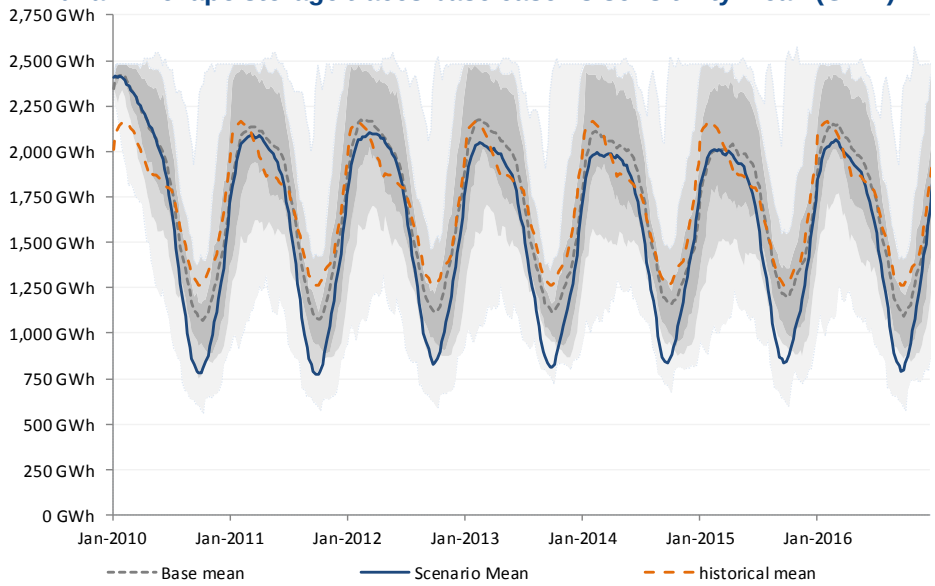


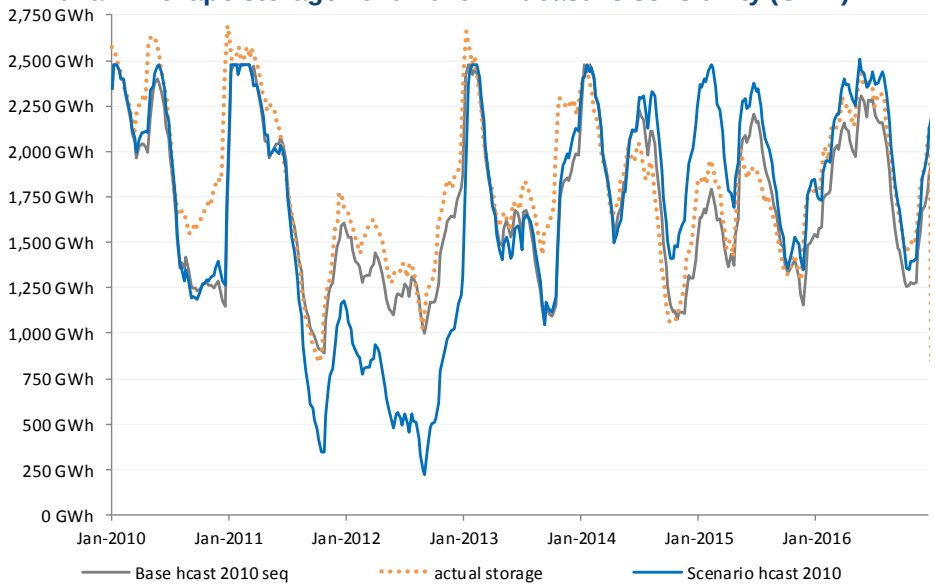
Sensitivity: enabling crude reserves & Kirschoff powerflow

0GWh SI "conservatism" in WV lookup, but keep inflow spreading & other heuristics, add reserves & Kirchoff

Pukaki+Tekapo storage traces base case vs sensitivity mean (GWh)



Pukaki+Tekapo storage 2010-2016 hindcast vs sensitivity (GWh)



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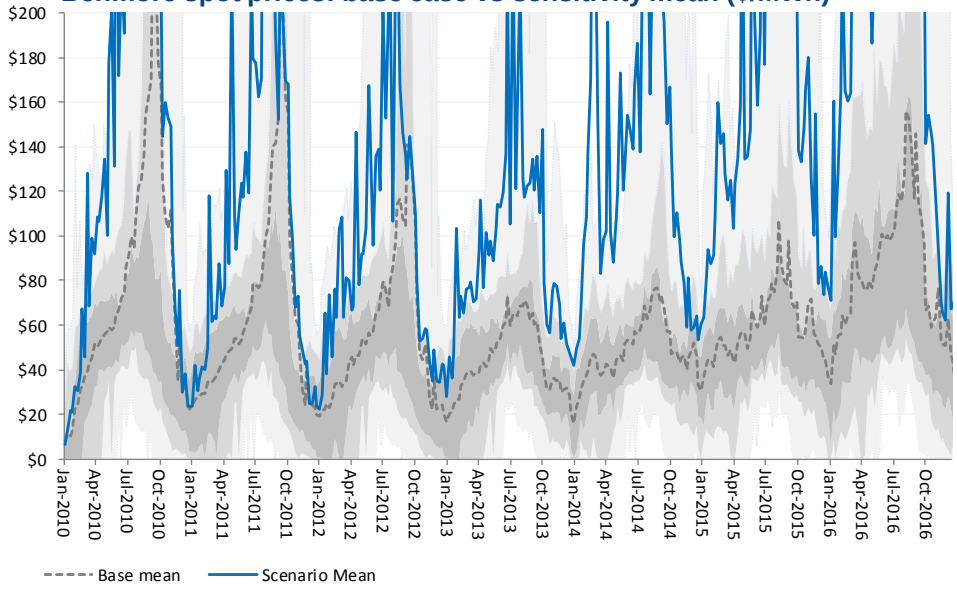

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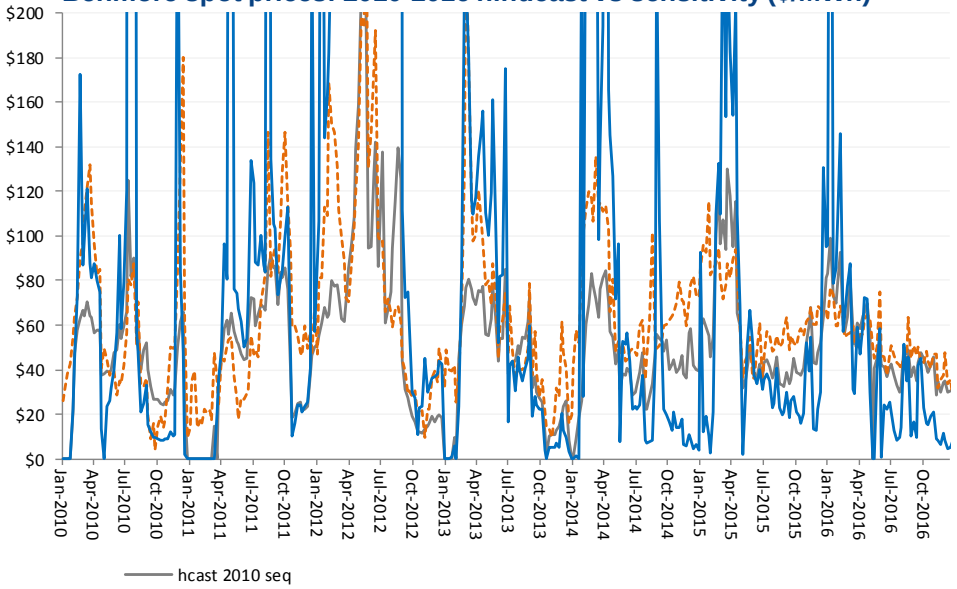
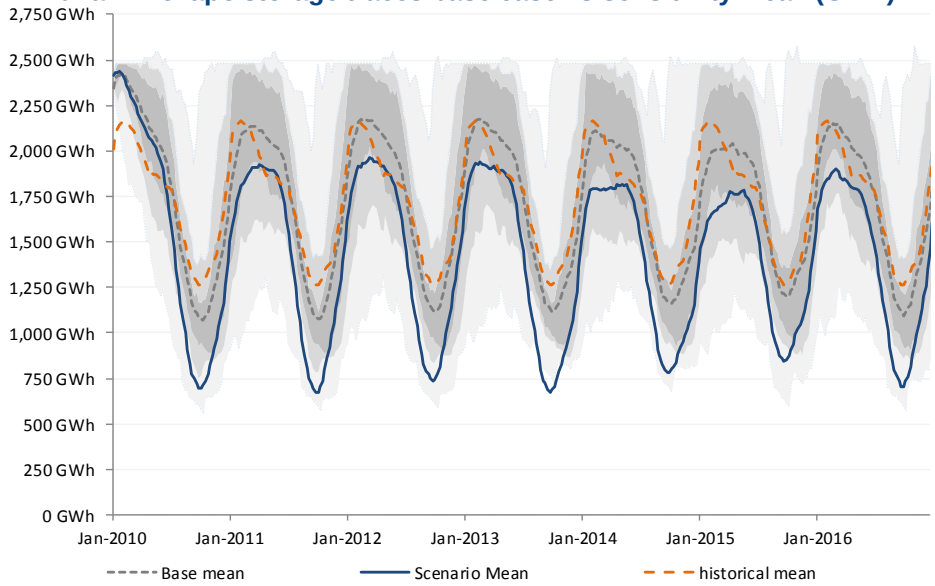


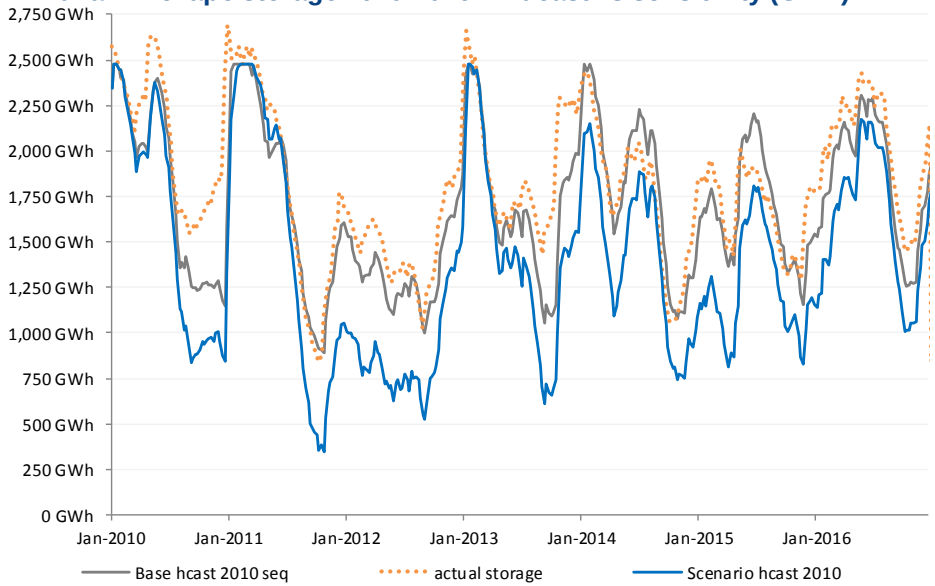
Sensitivity: Manapouri as a 3rd reservoir

Nil conservatism-margin, 4-week spread, 10-step grid (brings state-space to 4,650 entries, runtime 1.5hours)

Pukaki+Tekapo storage traces base case vs sensitivity mean (GWh)



Pukaki+Tekapo storage 2010-2016 hindcast vs sensitivity (GWh)



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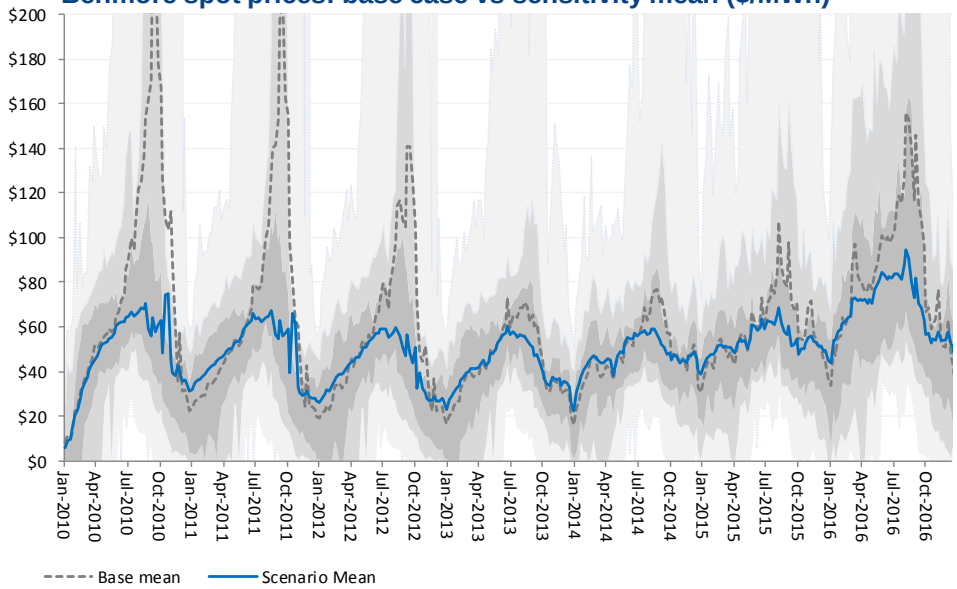

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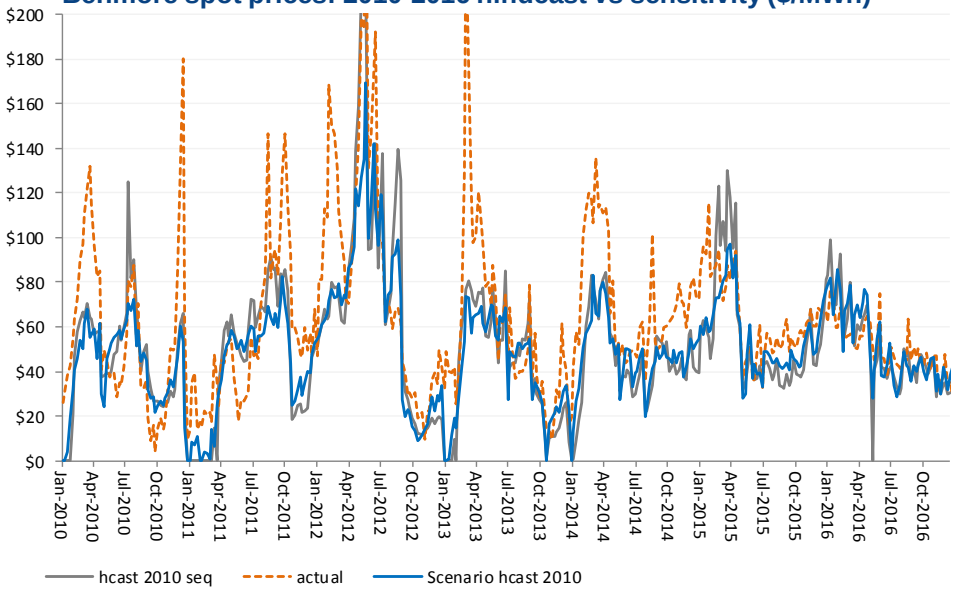
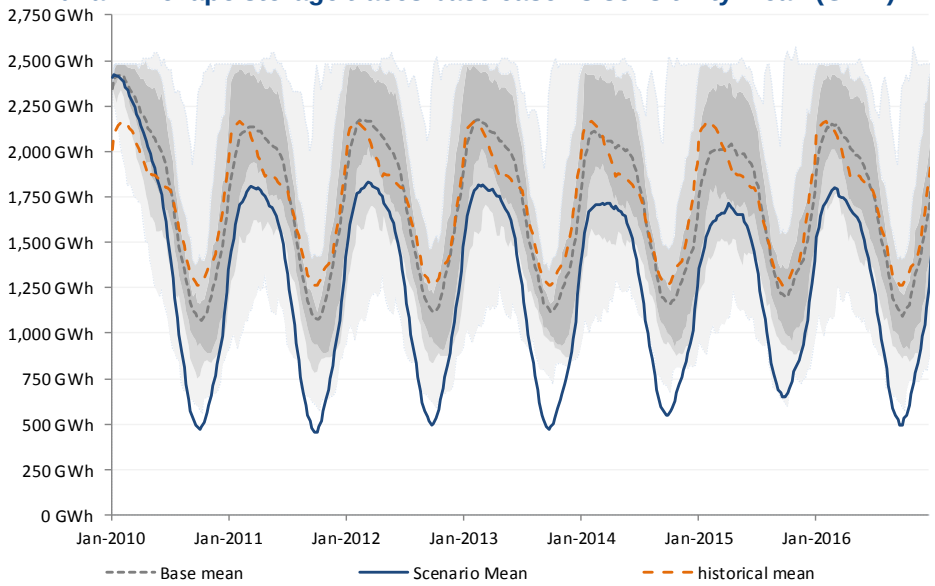


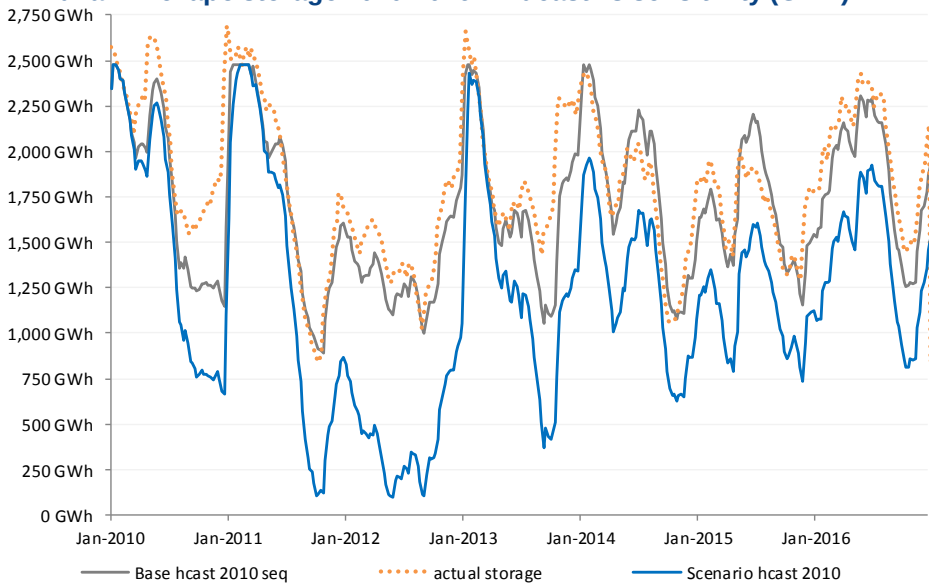
Sensitivity: “clean” implementation - ignore serial correlation

Remove all inflow spreading & heuristics, set 0GWh SI “conservatism”

Pukaki+Tekapo storage traces base case vs sensitivity mean (GWh)



Pukaki+Tekapo storage 2010-2016 hindcast vs sensitivity (GWh)



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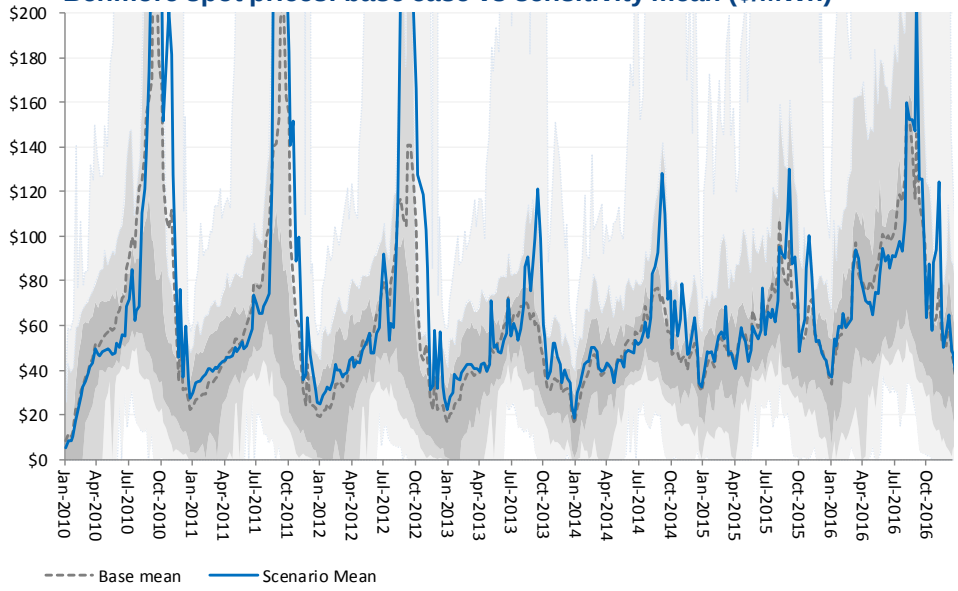

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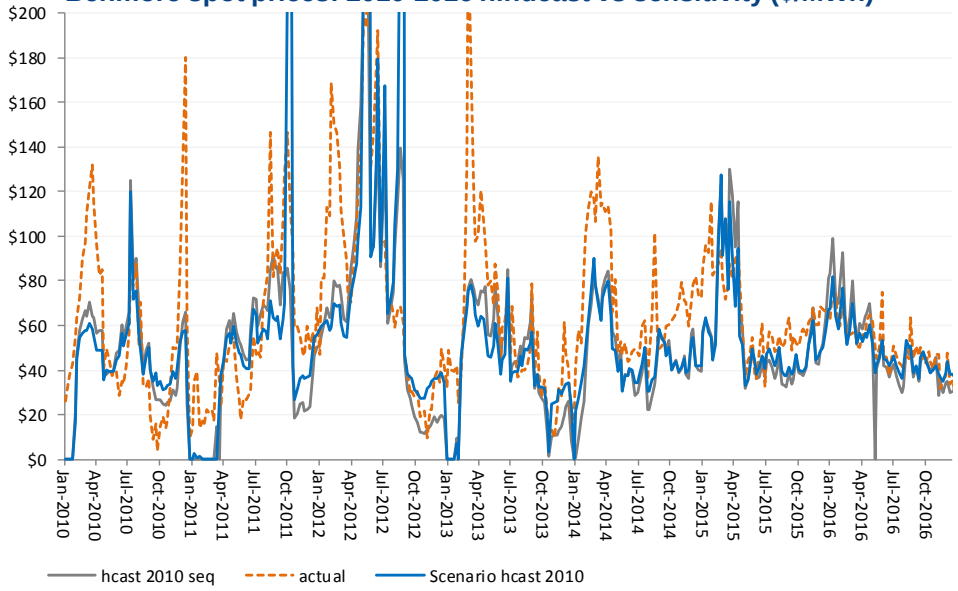

Observations & next steps

No model is ever “done” – still a work in progress…

Observations:

- **Our fairly straightforward CDDP implementation explains much of the observed market outcomes**, but required an extra conservatism placeholder (600GWh SI buffer) to fit hindcast and distribution storage traces.
- **Unsurprisingly, paring back heuristics & conservatism leads model to use much wider band of storage.**
- **But perhaps surprising that price distribution and 2010 hindcast prices were not much affected by conservatism settings** (and prices were higher if serial correlation was ignored)

Next steps:

- **Already has functionality to model thermal reservoirs** but requires further research to properly populate assumptions (and will treat fixed fuel-rate purchase decisions as exogenous)
- **Improve from crude reserves representation and improve grid resistance/susceptance parameter inputs** (the initial vSPD GDX extraction approach produced unreliable estimates)
- **Implement some equivalent to “grid-sim”** (check ex-ante water value surface aligns with ex-post simulation)
- **Wind variability** (wind speed vs inflow correlation, stochastic production per block)
- **Regulating power** (add regulating power constraint, in similar fashion to reserves?)

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