Assessing uncertainty of climate change impacts on long-term hydropower generation using the CMIP5 ensemble

Pablo E. Carvajal[1]

[1] UCL Energy Institute, University College London, *pablo.carvajal.14@ucl.ac.uk*

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Exploring hydropower's largest sources of uncertainty: impacts of climate change and capital cost overruns, and how to assess them in long-term energy system models.

INTRODUCTION

- Hydropower is vulnerable to long-term climate change. The Coupled Model Intercomparison Project (CMIP5) projects large uncertainty for precipitation.
- Large hydro suffers of significant cost and time overruns.
- Long-term energy system optimisation models usually consider constant hydro-climatic conditions and **only minimise cost, not risk**.

METHOD

INTEGRATED HYDRO - POWER – RISK MODEL

HYDROLOGICAL MODEL

- 40 GCMs RCP4.5 – 2001-2100 – monthly level – 0.5°grid res.
- Precipitation -> Runoff -> Availability factor for hydro (%)

TIMES ENERGY SYSTEM MODEL

Objective function

Minimising costs and risks simultaneously

Detail

- Horizon 2060
- 32 Time slices (12 months x 3 inter day periods)
- Plant by plant (125 existing plants) and 15 new technologies.
- Run of river and reservoir hydro by river basins and discrete sizes.

RISK MODEL

Upper Absolute Deviation

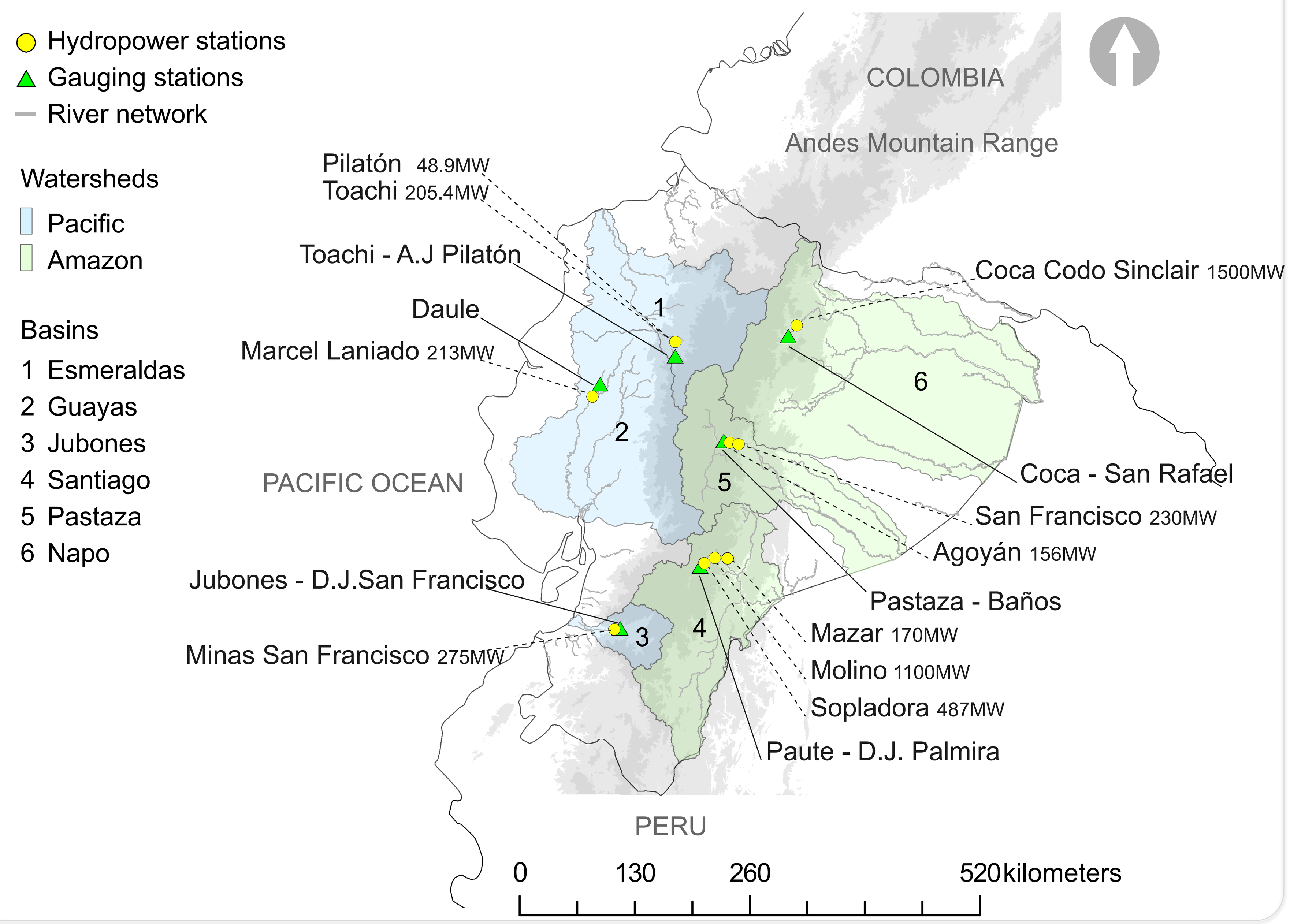
$$Min(E(cost) + \gamma \times UpAbsDev(cost))$$

$$UpAbsDev(cost) = \sum_j \left(p_j \times \{cost_j - E(cost)\}^+\right)$$

- The *UpAbsDev* computes the average value of the positive total cost deviations for all-states-of-the-world j (with probability p_j).
- Applied for **fuel prices** and **capital cost** of new technologies

CASE STUDY - ECUADOR

- Hydro share in electricity generation was 75% in 2017 – 4368MW
- Six large river basins with large hydro and still untapped potential.

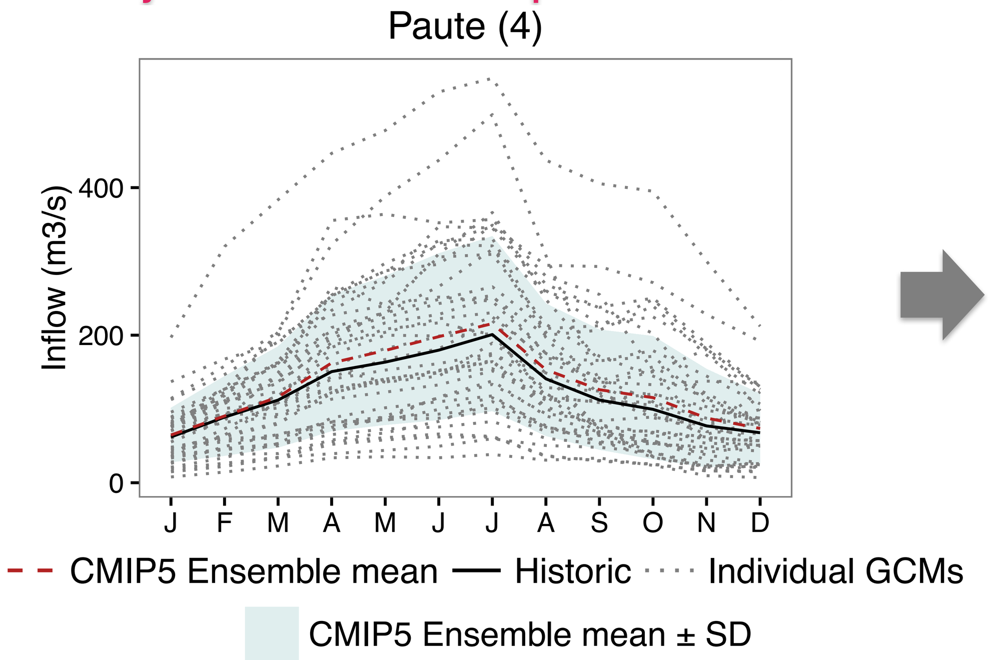


RESULTS

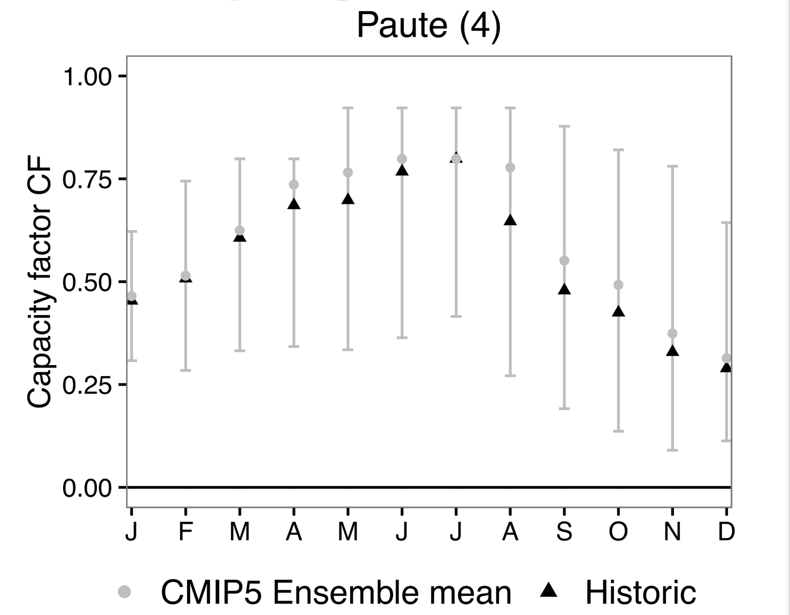
Runoff projections CMIP5 – RCP4.5* (2071-2100)

- Large discrepancy among climate models for precipitation
- Models reflect seasonal changes

Projected inflow compared to historic

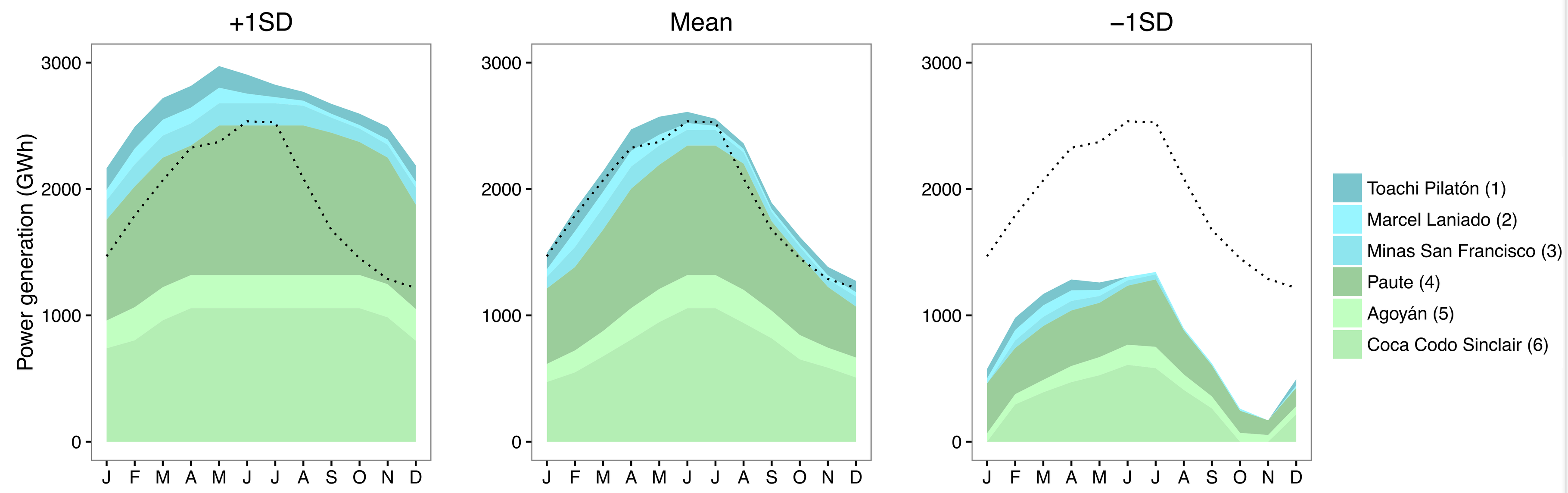


Capacity factors



Available energy from hydropower system in different basins

- Significant changes in expected hydropower production

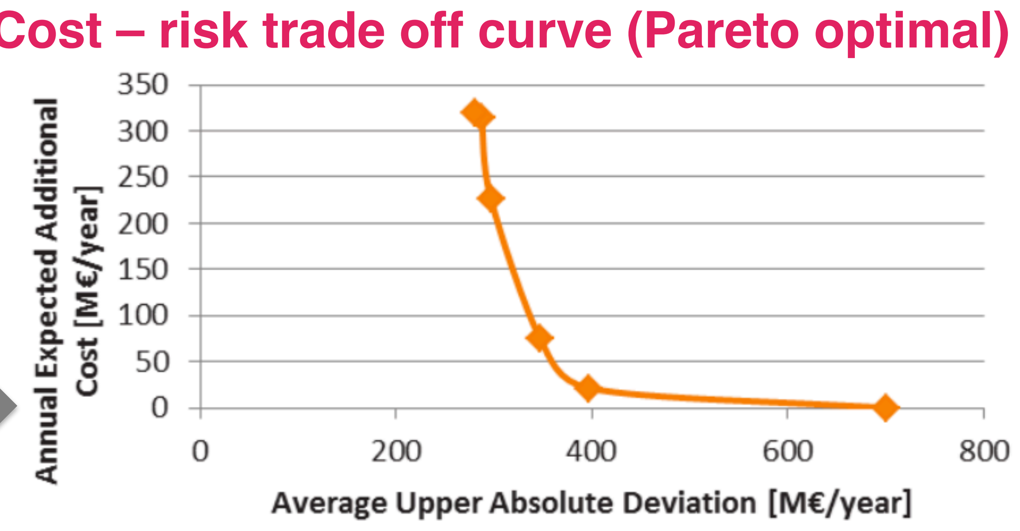


Installed capacity (MW)	Observed generation (GWh/y)	Simulated annual generation (GWh/y)		
		-1SD	Ensemble mean	+1SD
4368	20822	-55%↓	6%↑	39%↑

Next steps

- Consider changes in long-term hydro in TIMES for the whole Ecuadorian power system
- Include risk and derive a trade-off between system cost and risk

Cost – risk trade off curve (Pareto optimal)



*CMIP5 – Coupled Model Intercomparison Project IPCC AR5
RCP 4.5 Representative Concentration Pathway

CONCLUSIONS

- Power expansion plans (and energy system optimisation models) should consider minimum cost, minimum environmental impact and also minimum risk.
- The cheapest (minimal cost) portfolio might entail large uncertainties and price volatilities.
- There are still large discrepancies and uncertainties for future hydropower production under climate change.

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