

Adapt to what? Projections of direct impacts of climate change on surface reservoir water quality in Australia and Taiwan

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APEC Climate Symposium, Nanjing, China, 27-29 October 2014



Australian
Water
Quality
Centre



global wATER quality
research center



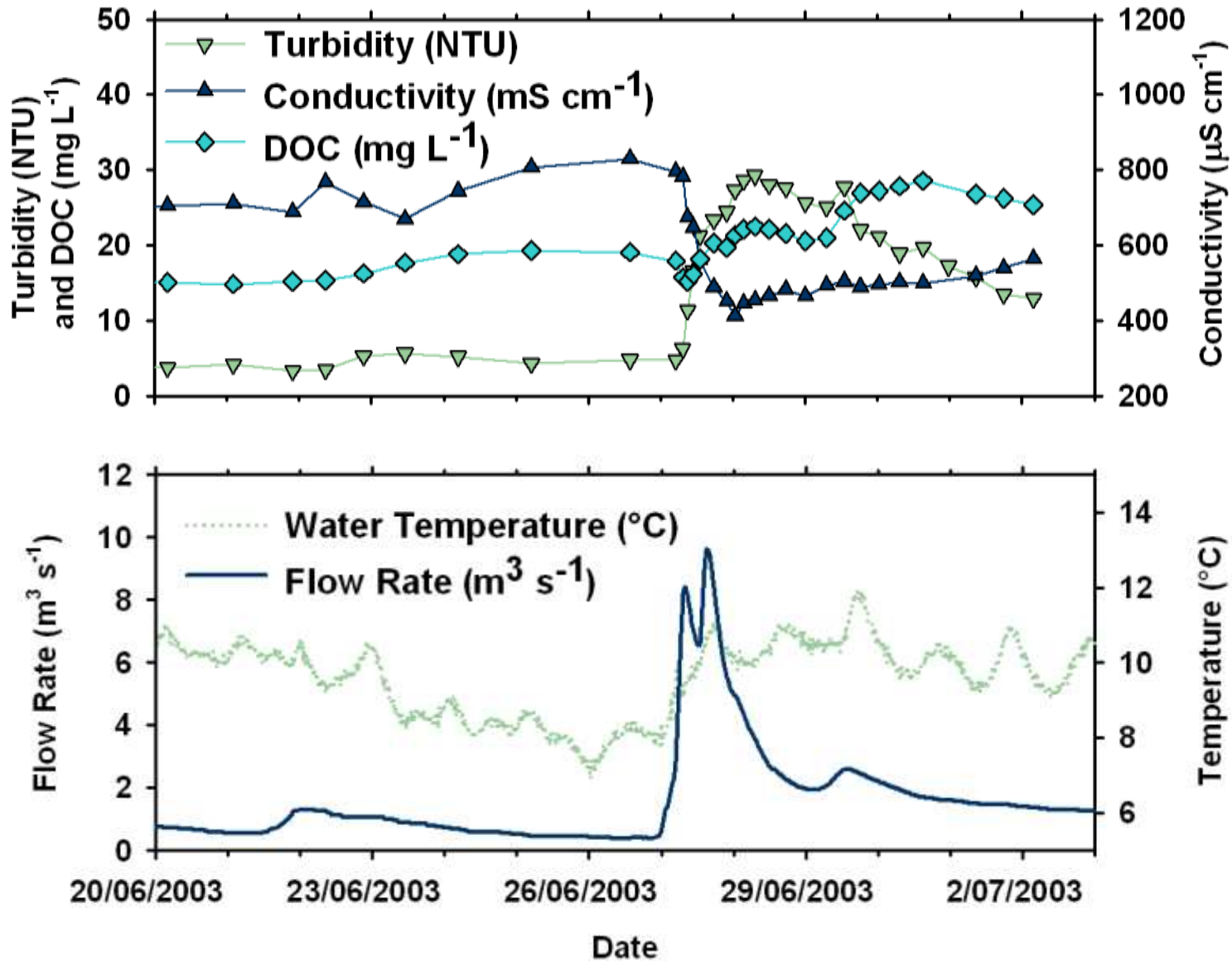
Overview

- Goals
 - 2 examples
- Case study locations
- Climate change
 - Water quality
- Water quality models
- Model Scenarios
- Future Directions
 - Comprehensive assessment



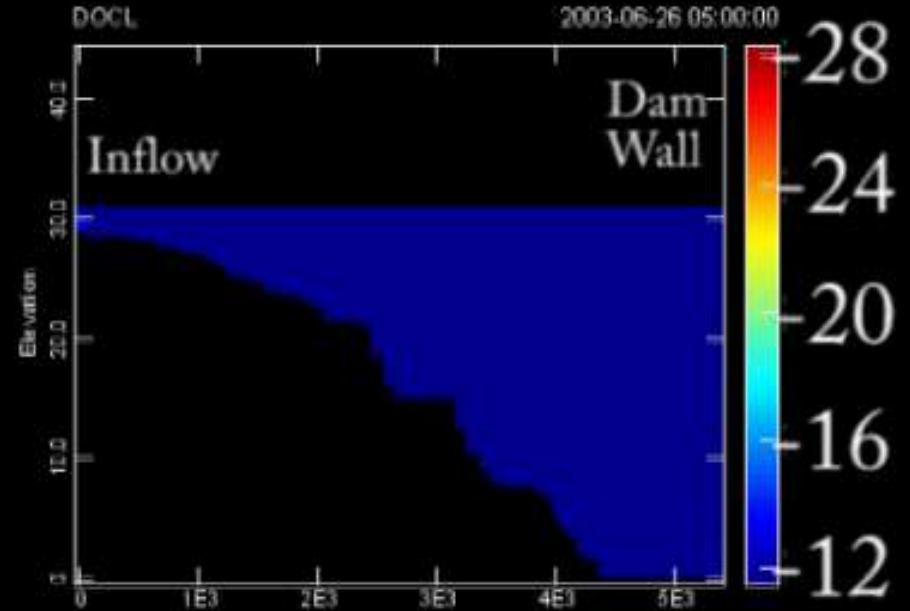
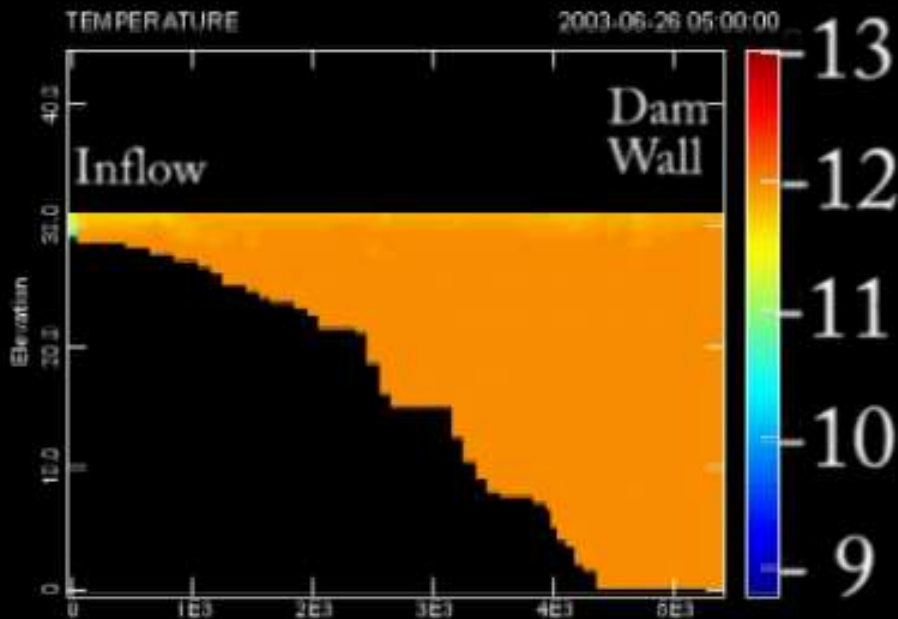
Goals: Use models to facilitate

- Operational responses to hydro-meteorological hazards
 - Inflow events to reservoirs (pathogens and turbidity spikes)
 - Growth of cyanobacteria (blue-green algae)
- Prudent investment in infrastructure
 - Water resources (allocation, dams)
 - Water management infrastructure (mixers and multi-level offtakes)
 - Water treatment infrastructure (water filtration plants)
 - Water delivery infrastructure (demand and development)

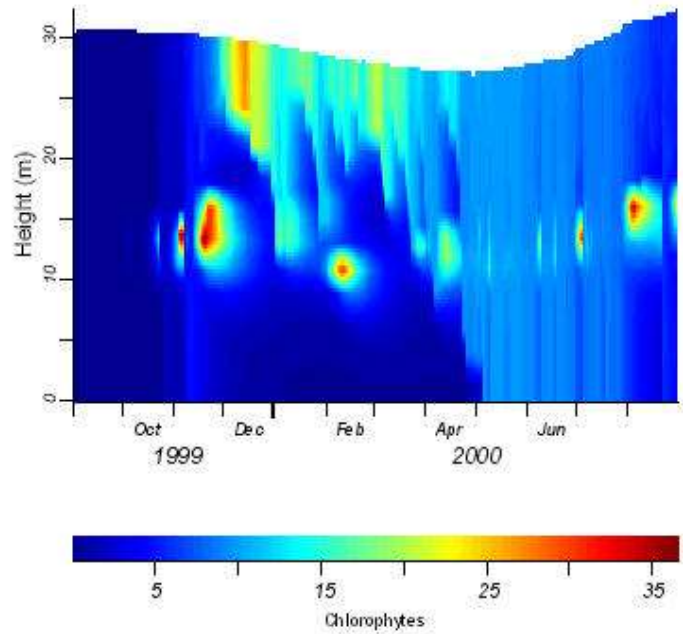


Temp ($^{\circ}\text{C}$)

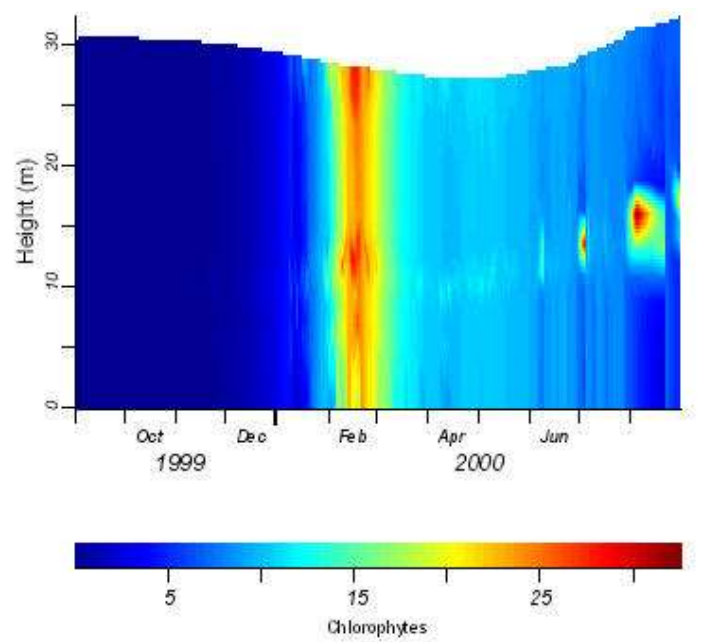
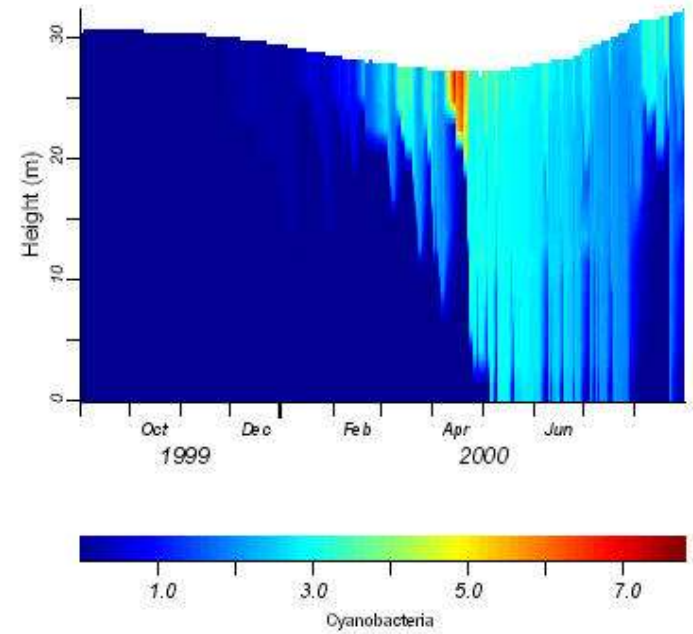
DOC (mg/L)



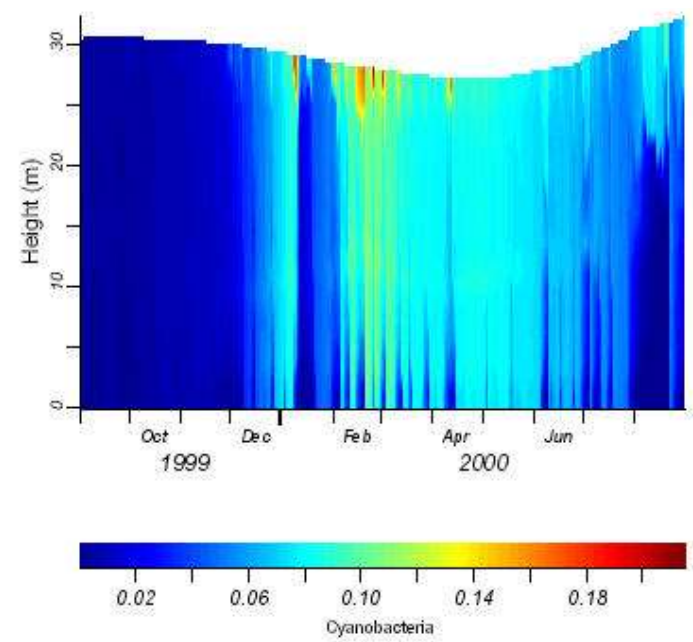
Inflow of riverine intrusion into Myponga Reservoir simulated with ELCOM-CAEDYM for 15 days after 65 mm rainfall event. The longitudinal cross section of the reservoir is shown



No
Mixing



Mixing





Nanjing



Hsinshan Reservoir



Happy Valley Reservoir

Google

Sign in

North Pacific Ocean

China

South Korea

Japan

East China Sea

Hsinshan Reservoir

South China Sea

Thailand

Myanmar (Burma)

India

Bay of Bengal

Gulf of Thailand

Malaysia

Indonesia

Banda Sea

Arafura Sea

Papua New Guinea

Coral Sea

Indian Ocean

Australia

NT

QLD

WA

SA

NSW

ACT

VIC

TAS

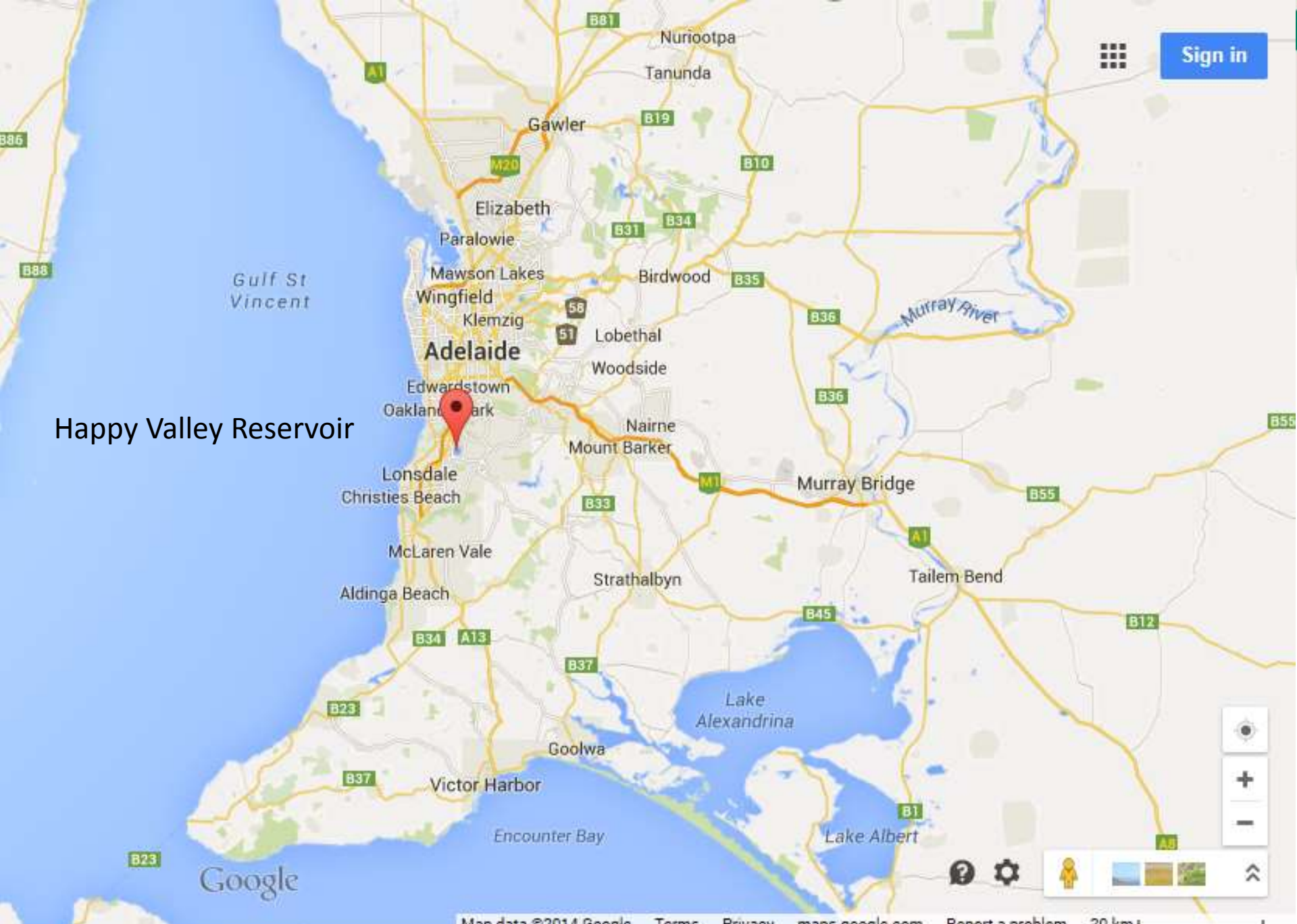
Great Australian Bight

Tasman Sea

New Zealand







Happy Valley Reservoir

Gulf St Vincent

Adelaide

Murray River

Lake Alexandrina

Lake Albert

Google

Sign in

The Onkaparinga Head Works

Happy Valley
Water Filtration Plant

Happy Valley
Reservoir
11,600 ML
(9,400 acre-feet)

Aqueduct

Clarendon
Weir

Sea

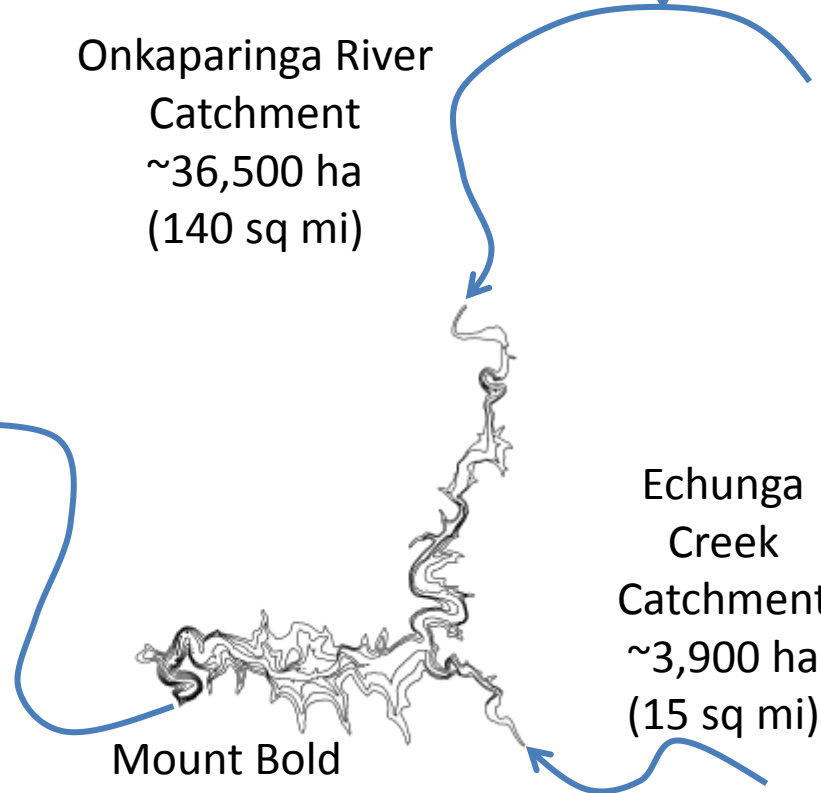
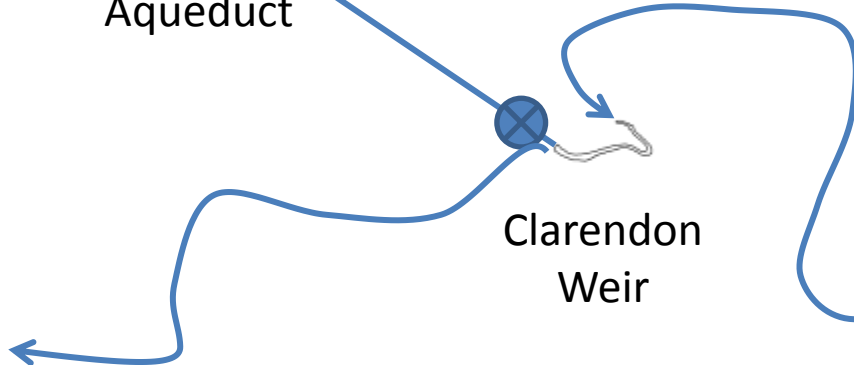
To scale: Reservoirs shown with 10m contours

Onkaparinga River
Catchment
~36,500 ha
(140 sq mi)

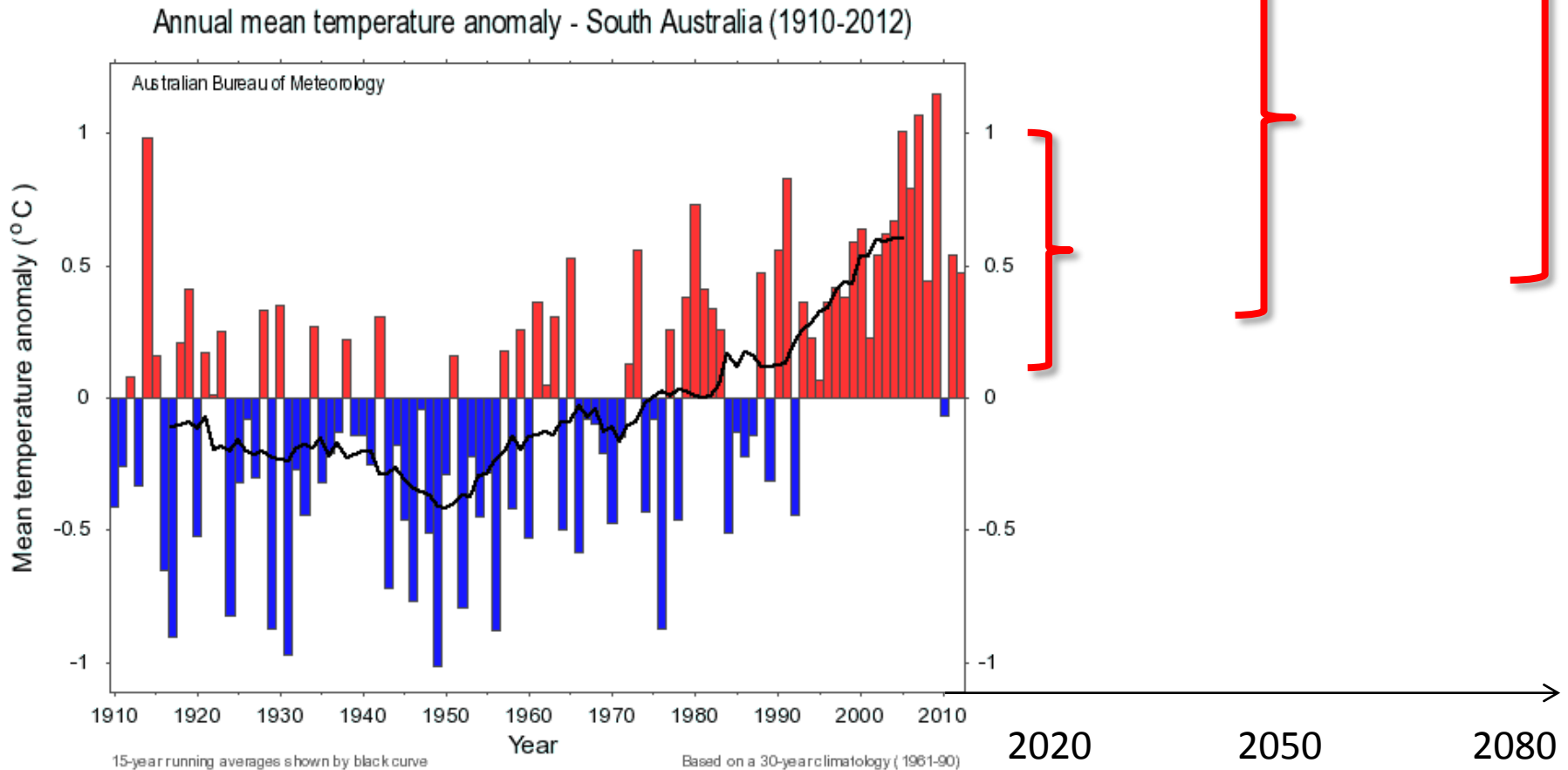
Mount Bold
Reservoir
46,180 ML
(37,400 acre-feet)

Murray Bridge –
Onkaparinga Pipeline

Echunga
Creek
Catchment
~3,900 ha
(15 sq mi)

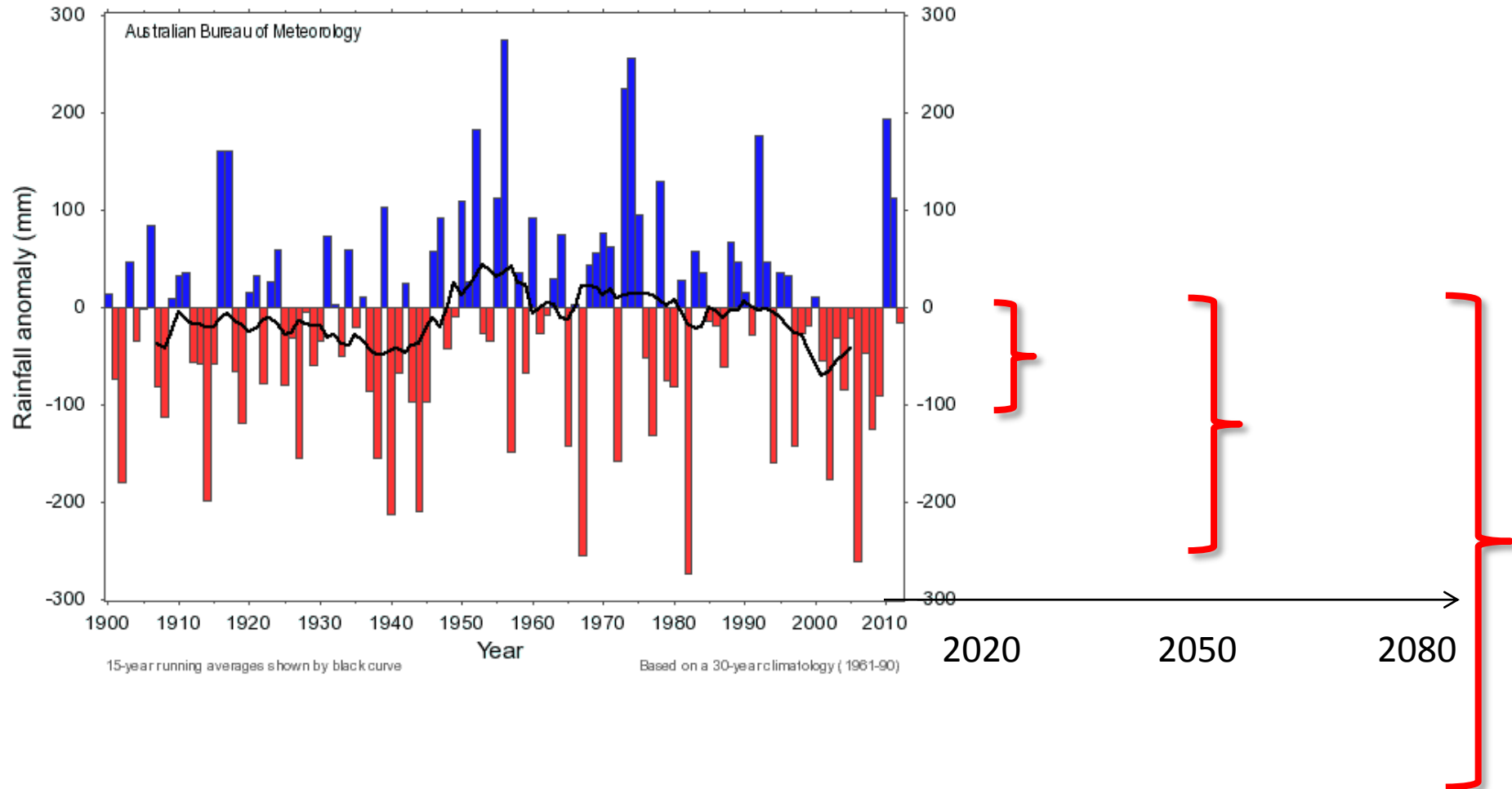


Projected temperature rises for South Australia



Projected precipitation for South-eastern Australia

Annual rainfall anomaly - Southeastern Australia (1900-2012)

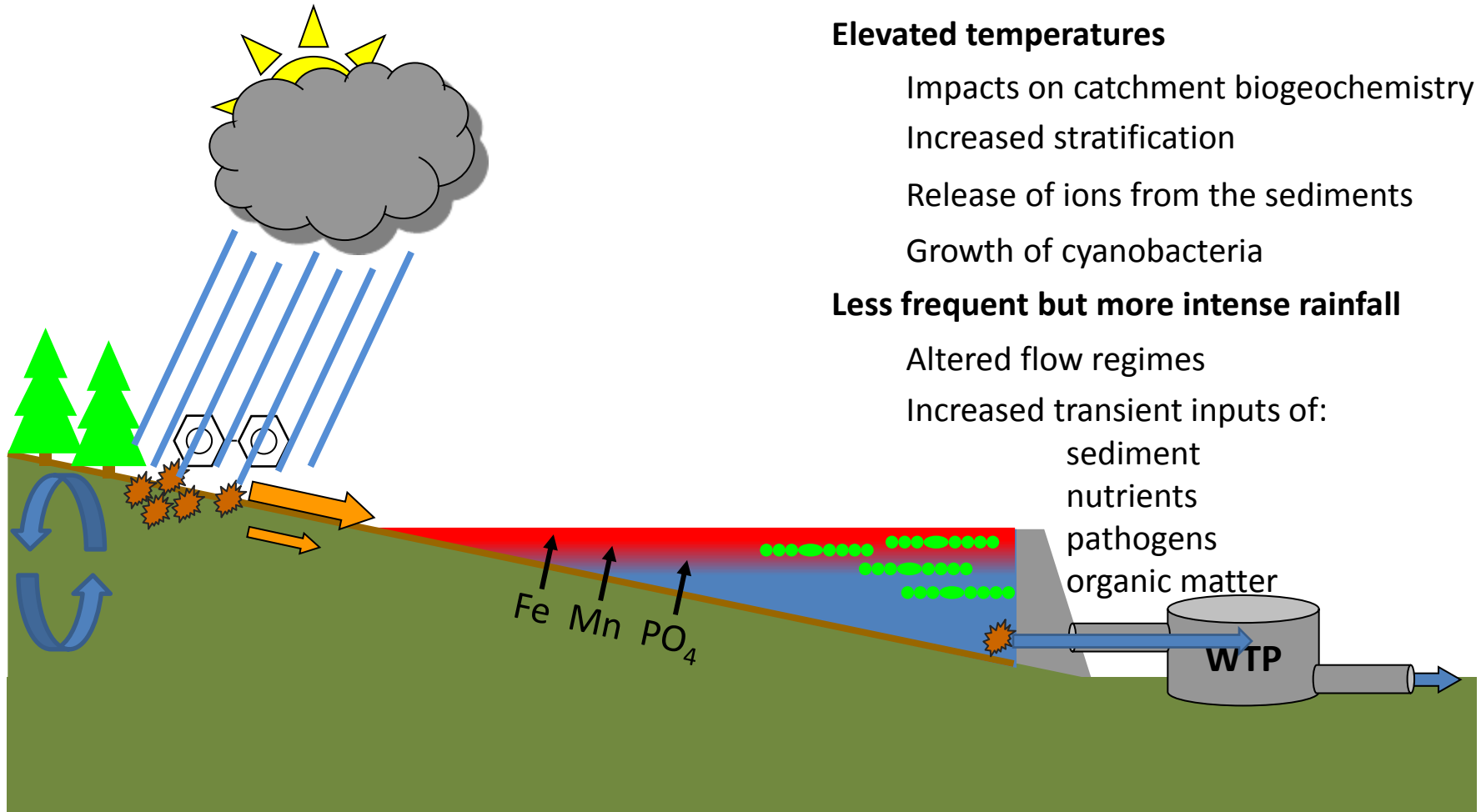


Potential CC impacts on the water supply business

- Cost
 - Assets / Investments
 - Energy (pumping, desalination and price)
 - Coagulants ←
 - Disinfectants ←
- Compliance
 - Pathogens / DBPs / Toxins ←
 - Outfalls
 - Greenhouse gas emissions
- Customers
 - Aesthetics / tastes and odours ←
 - Demand

Water
Quality
Impacts

Potential climate change impacts on water quality



Elevated temperatures

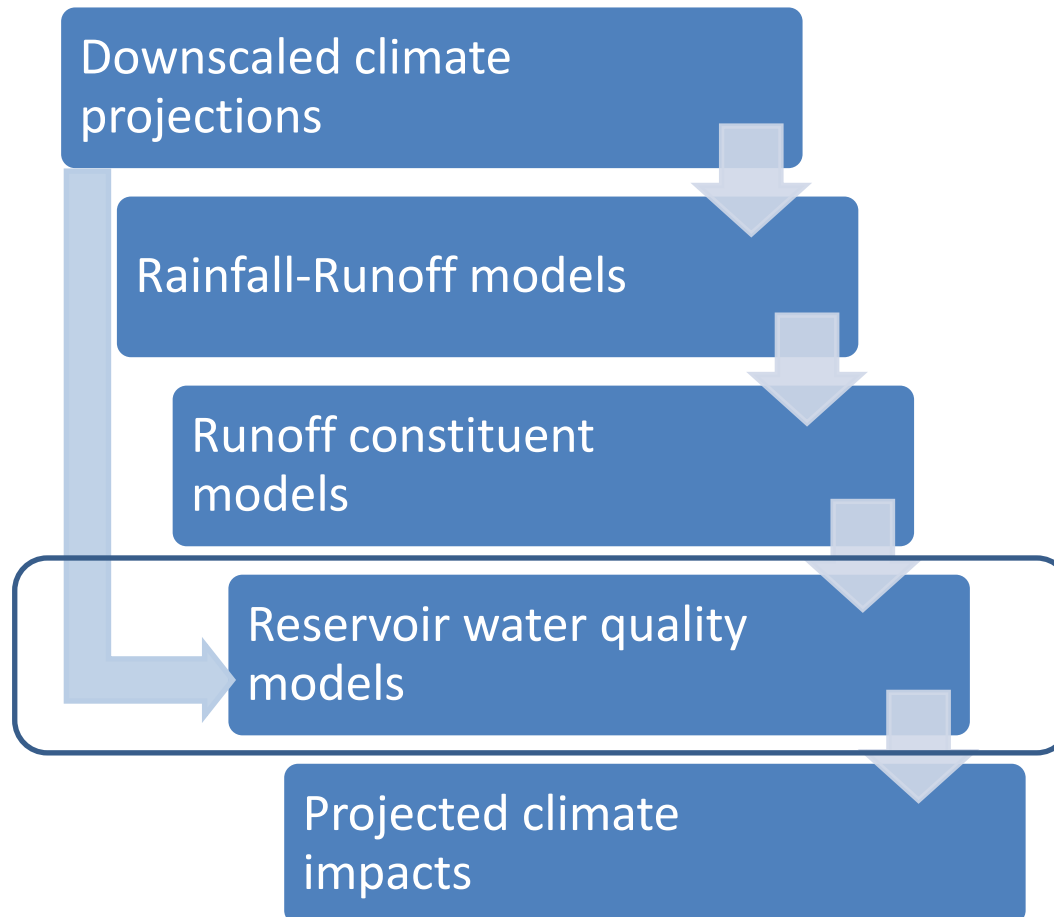
- Impacts on catchment biogeochemistry
- Increased stratification
- Release of ions from the sediments
- Growth of cyanobacteria

Less frequent but more intense rainfall

- Altered flow regimes
- Increased transient inputs of:
 - sediment
 - nutrients
 - pathogens
 - organic matter

Climate change impact assessment methodology

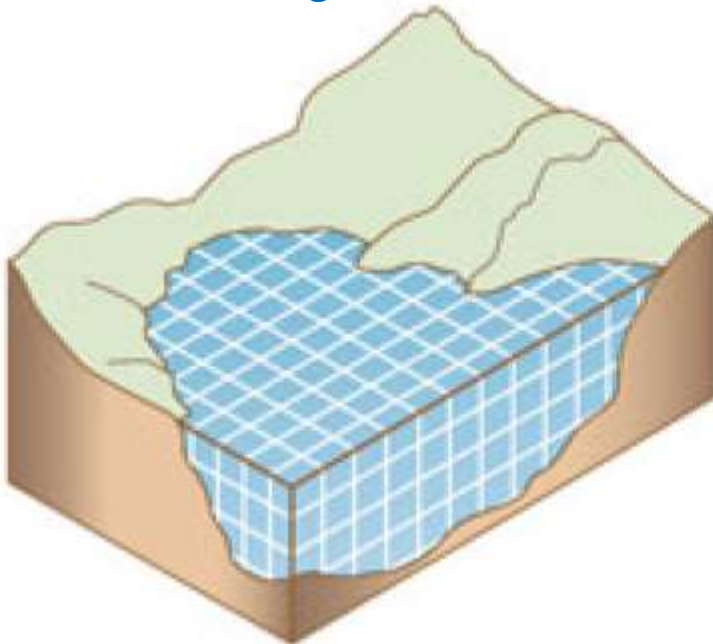
Cascade of Uncertainty



Hydrodynamic Models

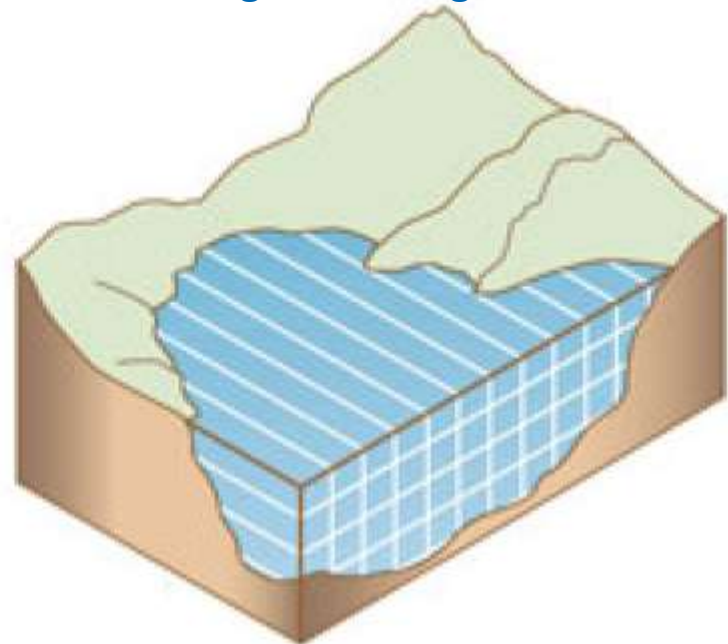
ELCOM– Happy Valley

- 3D; 100m lateral; 0.5m vertical
- 50s time step (Oct 2005 – Apr 2006)
- Meteorological forcing
- Artificial mixing



Ce-Qual-W2 - Hsinshan

- 2D laterally averaged
- Daily time step (2004 – 2012)
- Fixed layer thickness (1 m)
- Meteorological forcing



Water Quality Models

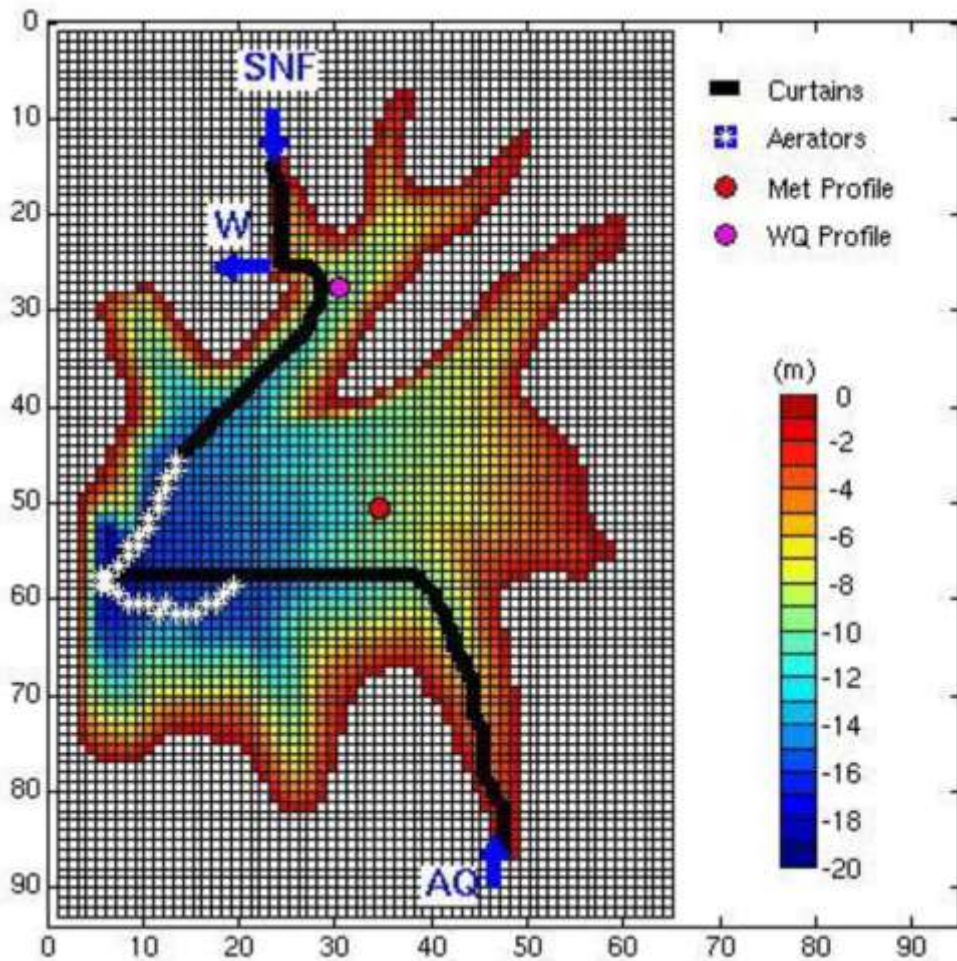
CAEDYM – Happy Valley

- Phytoplankton (2)
 - Cyanobacteria
 - Chlorophytes
- Dissolved oxygen
- Nutrients
 - carbon, nitrogen, phosphorus
- Iron and Manganese
- Suspended Solids

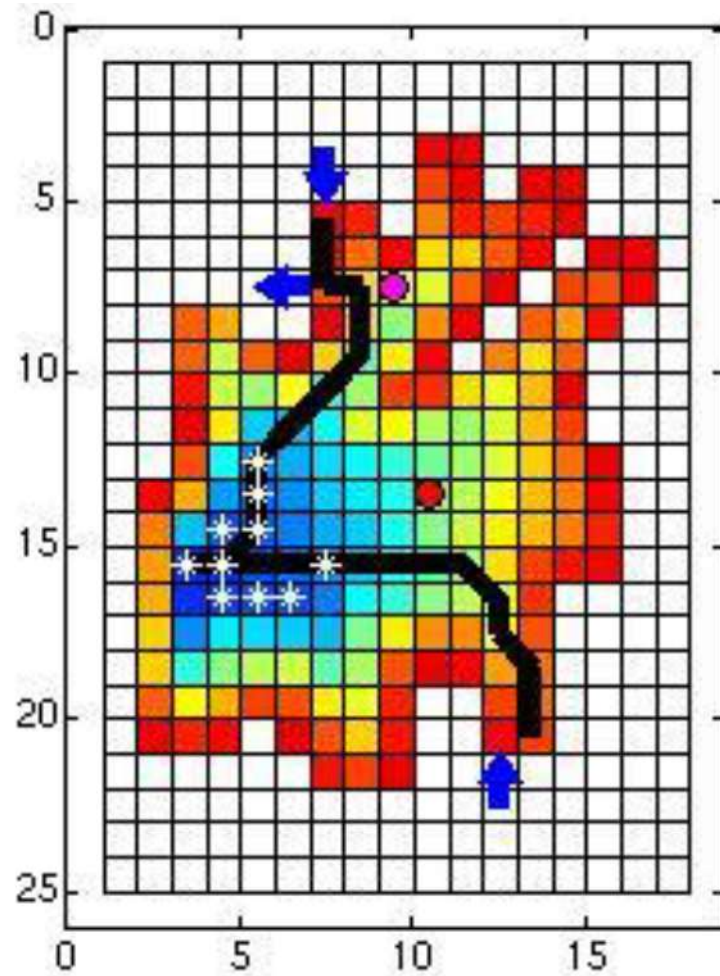
Ce-Qual-W2 - Hsinshan

- Phytoplankton (1)
- Dissolved oxygen
- Nutrients
 - carbon, nitrogen, phosphorus
- Inorganic carbon
- Organic matter
 - Dissolved
 - Particulate

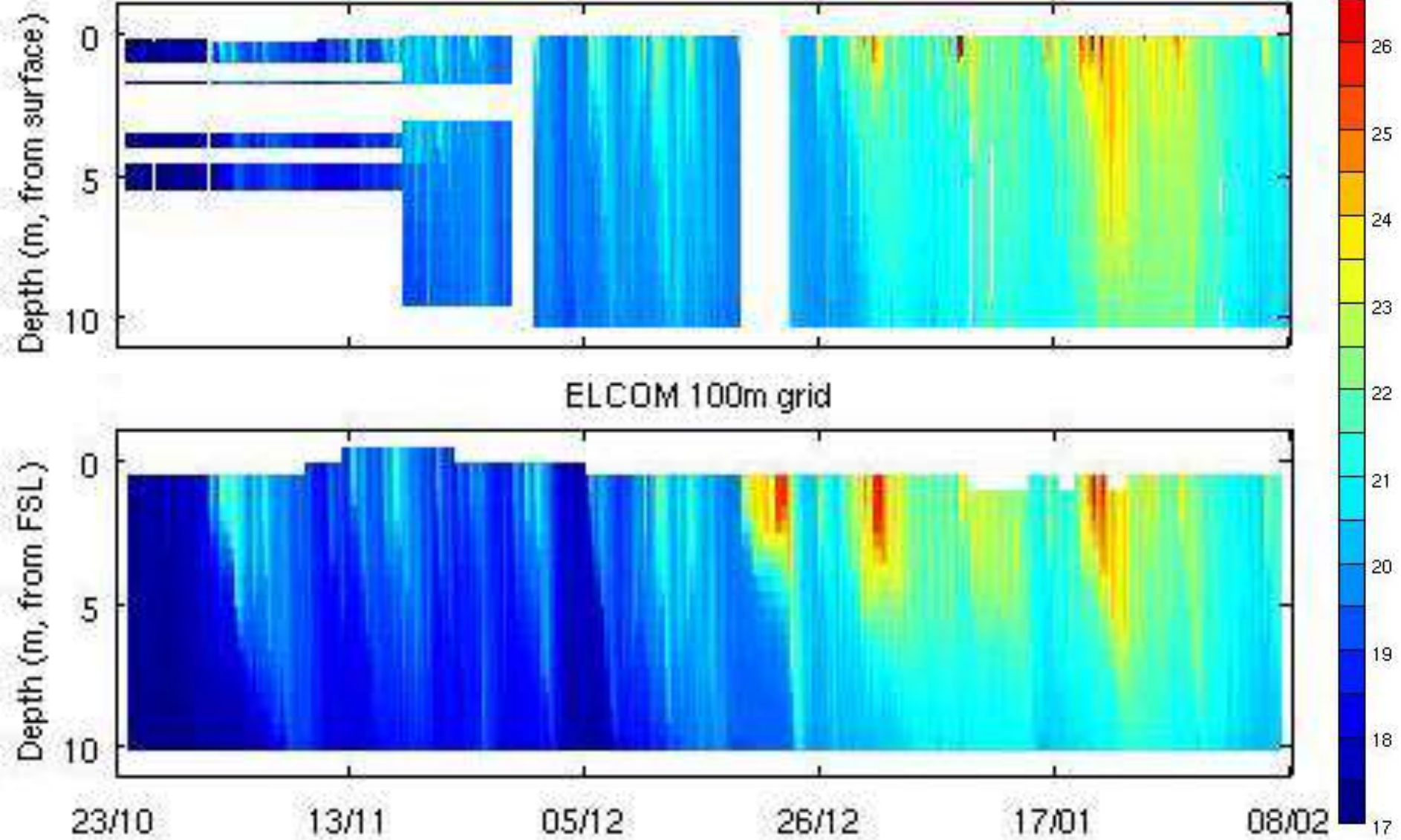
25m grid

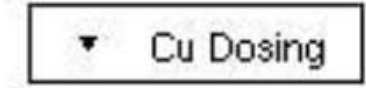
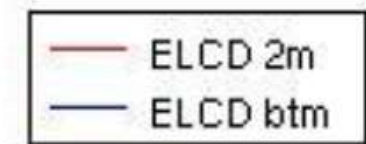
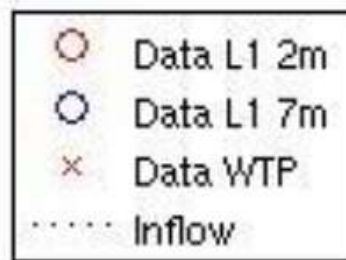


100m grid

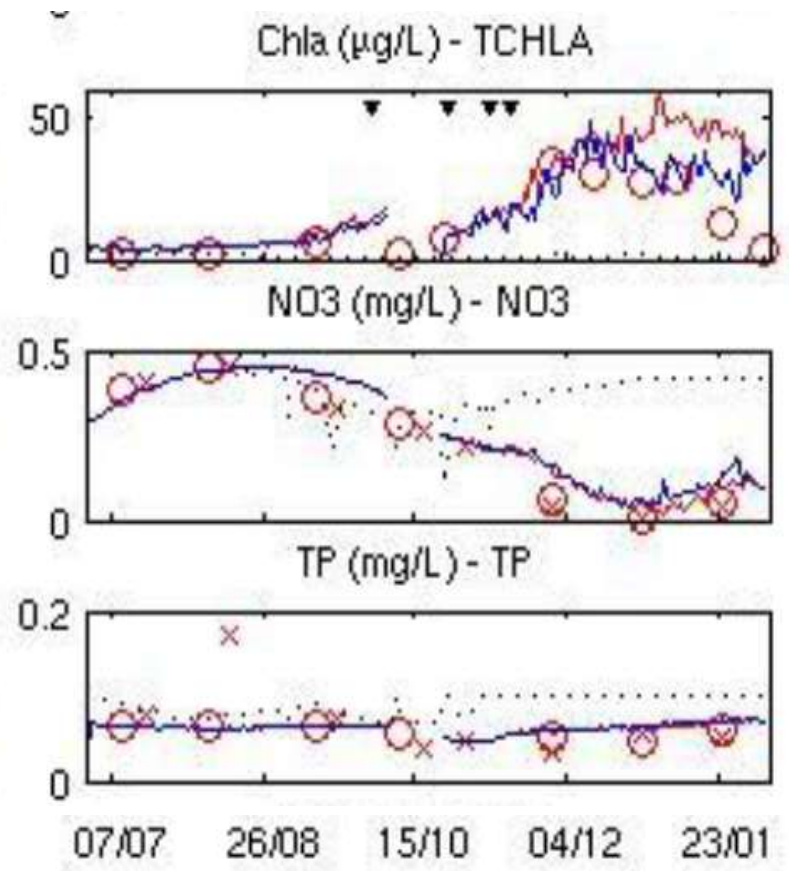
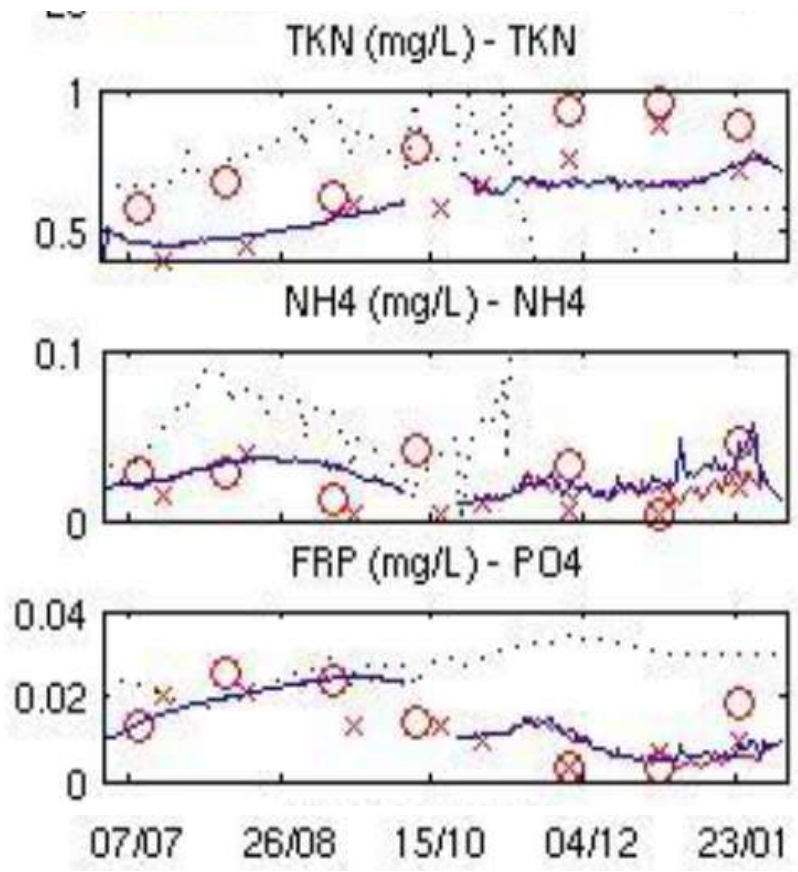


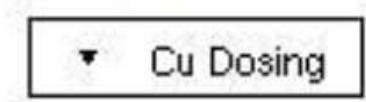
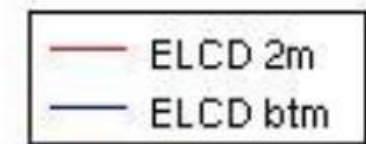
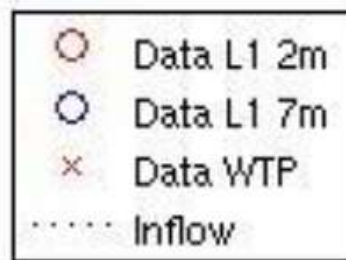
SUMMER - TChain Data



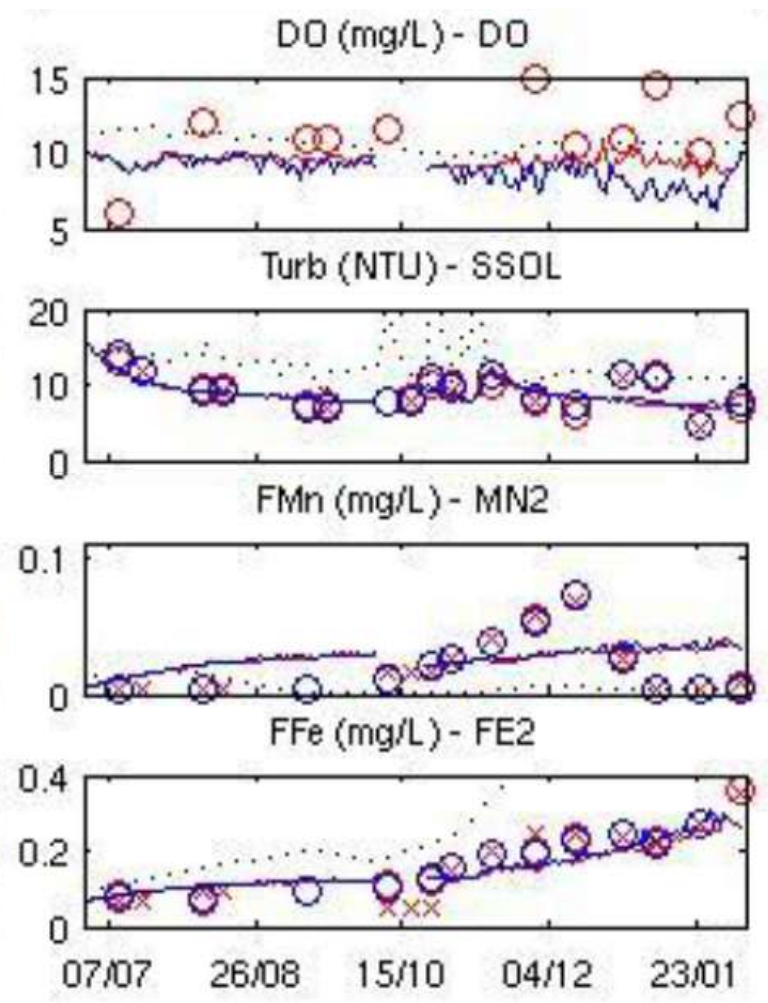
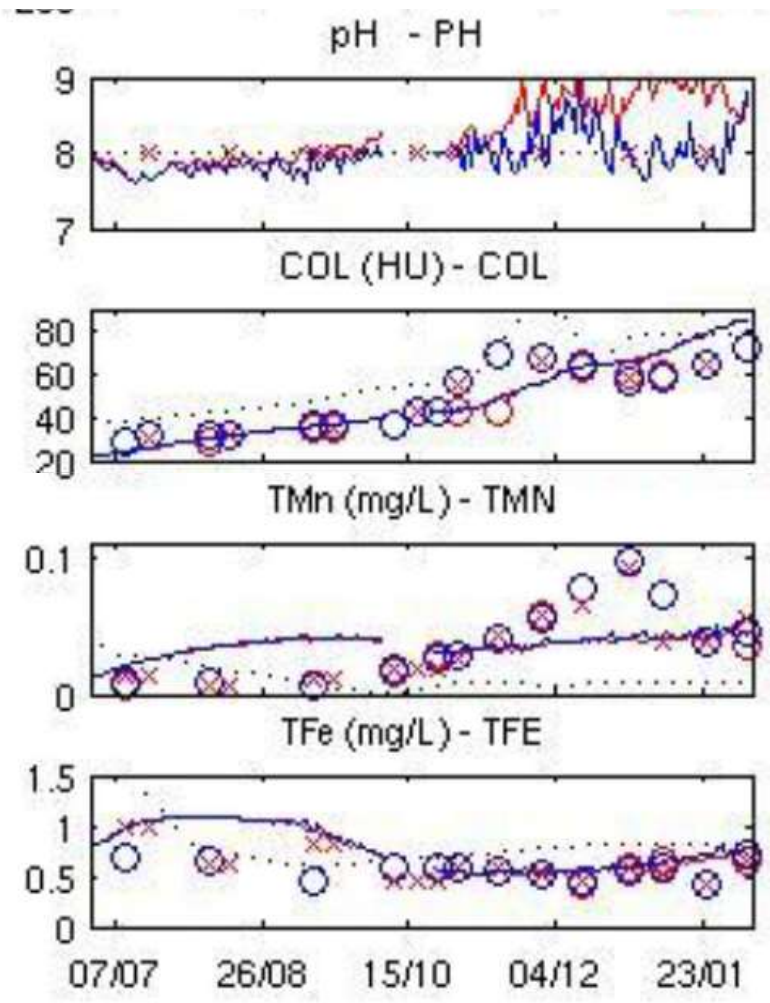


Base Model Performance





Base Model Performance



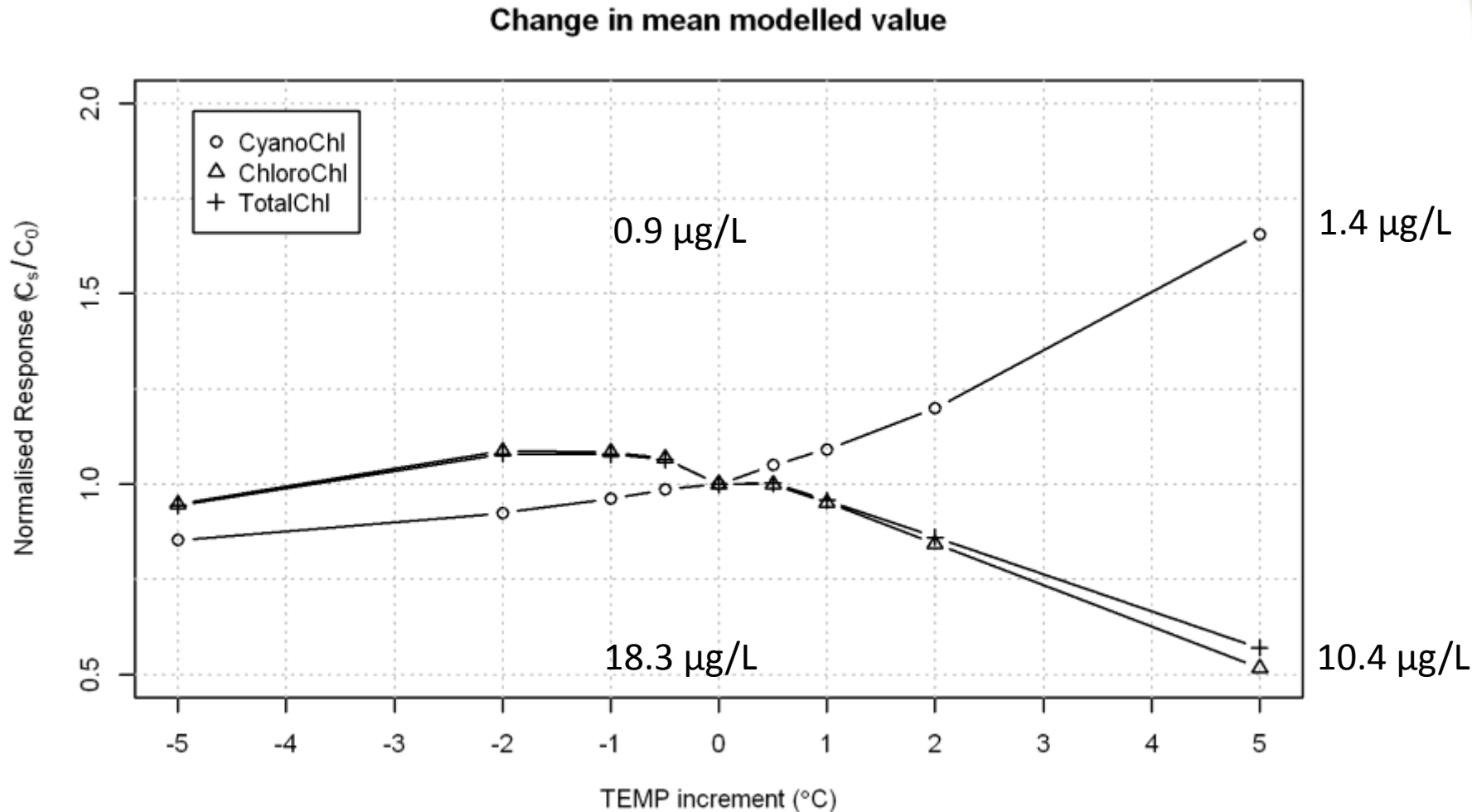
Scenarios Applied – ELCOM-CAEDYM @ Happy Valley Reservoir

- TEMP
 - Air and inflow
- FLOW
 - Inflow
 - Aquaduct
 - Supernatant return
 - Outflow
- WIND
 - Wind speed

	Temperature (TEMP) <i>[increment]</i>	Precipitation (FLOW) <i>[multiplier]</i>	Wind Speed (WIND) <i>[multiplier]</i>
	-5.0	0.50	0.50
	-2.0	0.75	0.75
	-1.0	0.90	0.90
	-0.5	0.95	0.95
	0.5	1.05	1.05
	1.0	1.10	1.10
	2.0	1.25	1.25
	5.0	1.50	1.50

- Single summer simulation (05/06)

Modelled Chlorophyll Sensitivity to TEMP



Does empirical evidence support this?

- Historical data analysis (1997 – 2012)
- Monthly normals and anomalies
 - water temperature
 - Total chlorophyll a
- Linear Regression (Chla ~ Temp)
 - $R^2 \sim 0$
 - Positive but non-significant slope estimate.

Taipei City



Hsinshan Res. Catchment

Hsinshan WTP

Badu pumping station

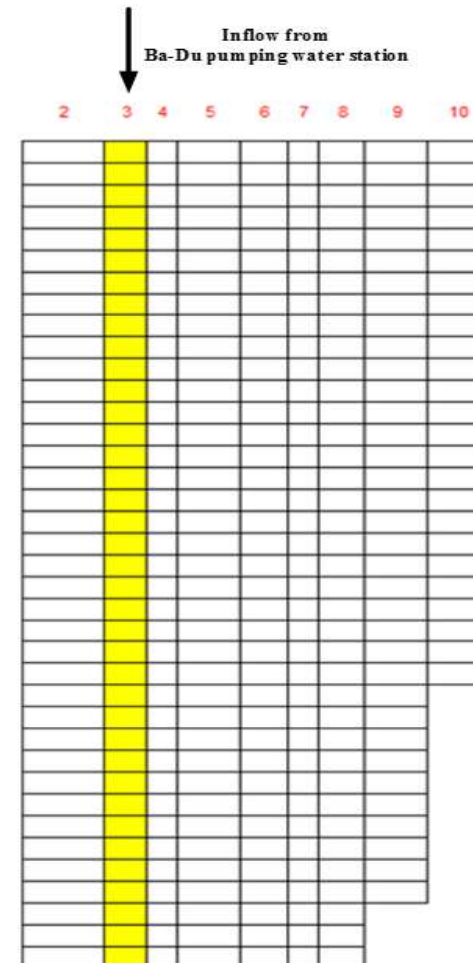
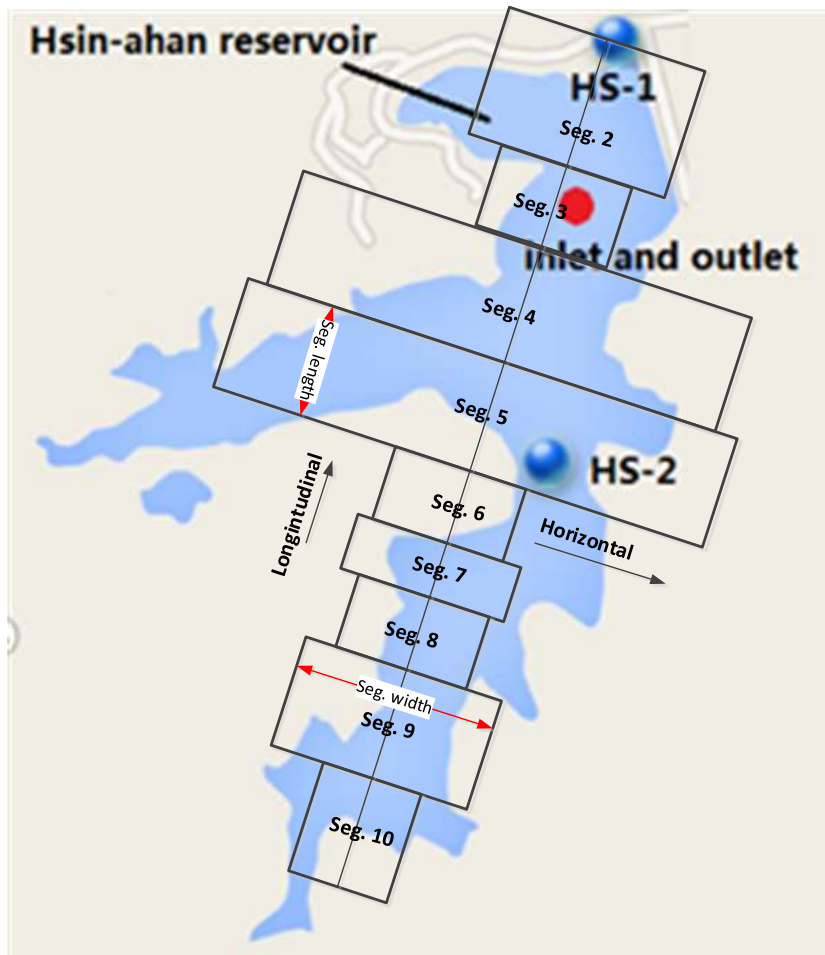
Keelung River

Keelung River Catchment

New Taipei City

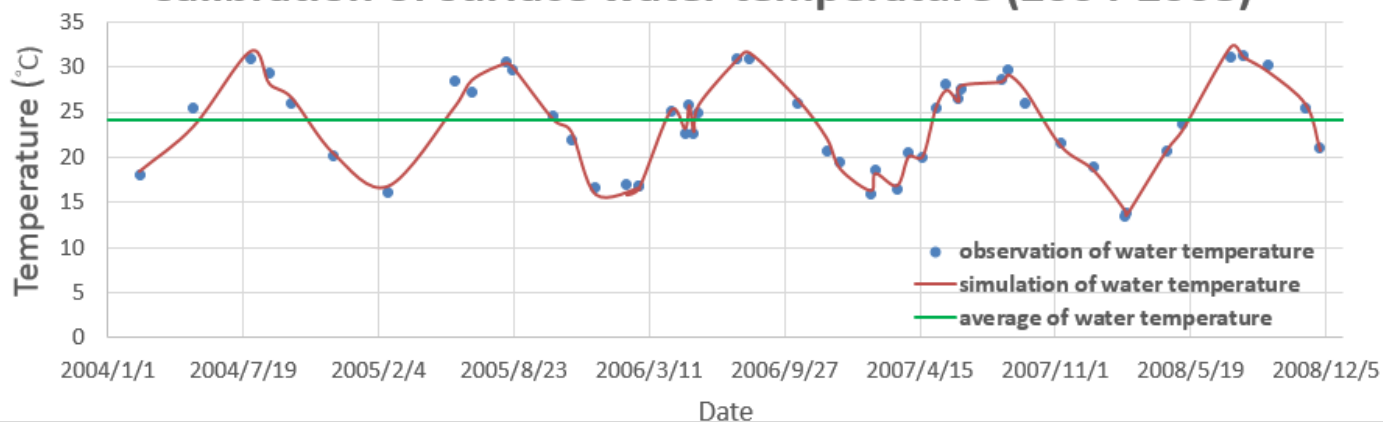
Keelung City





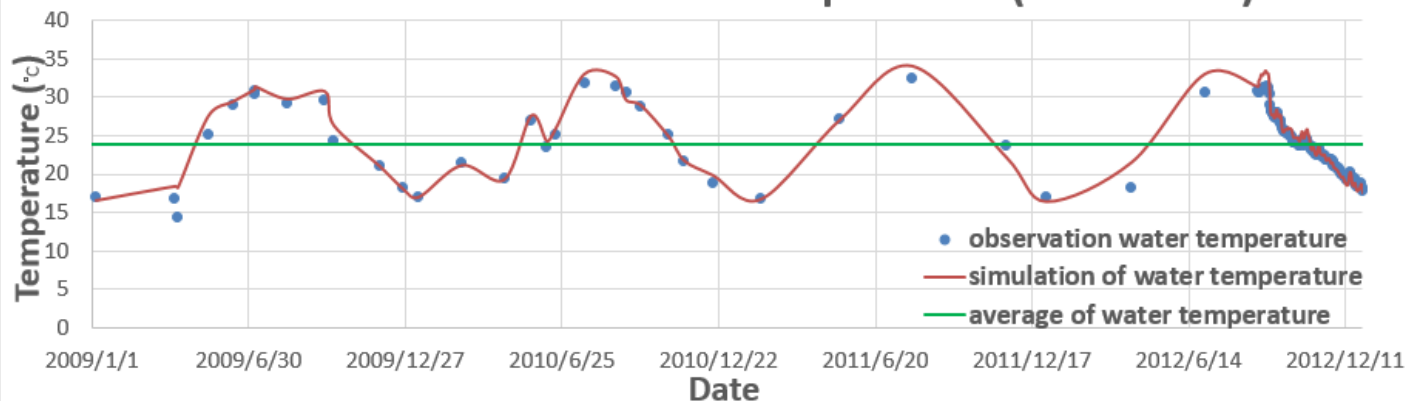
Surface water temperature (0.5m) Hsinshan Reservoir

Calibration of surface water temperature (2004-2008)



AME = 0.59°C

Validation of surface water temperature (2009-2012)



AME = 0.68°C

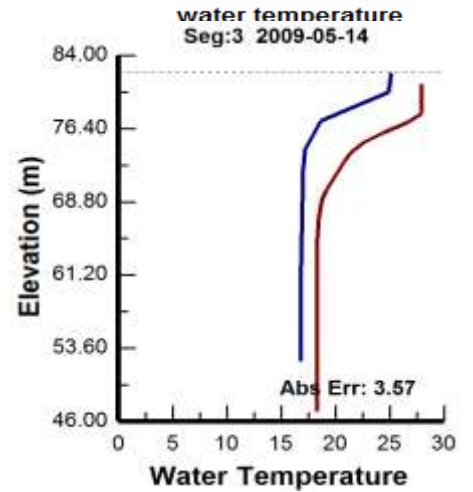
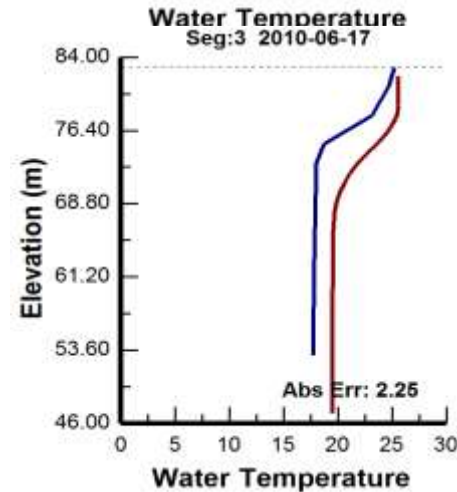
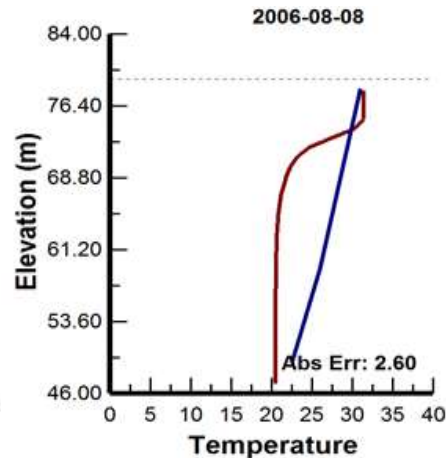
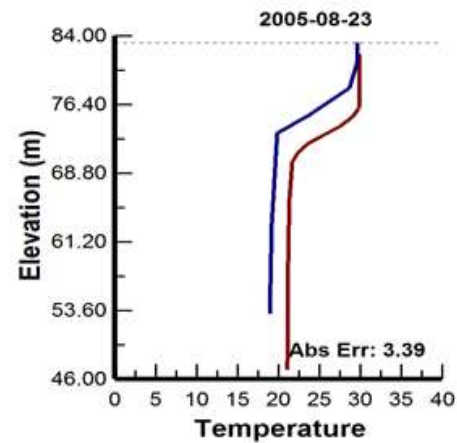
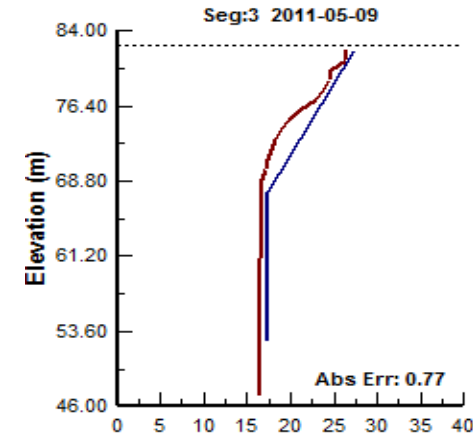
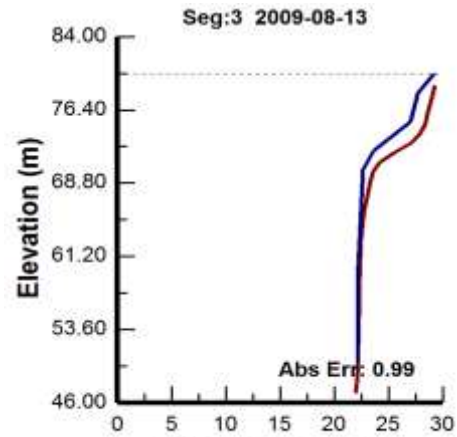
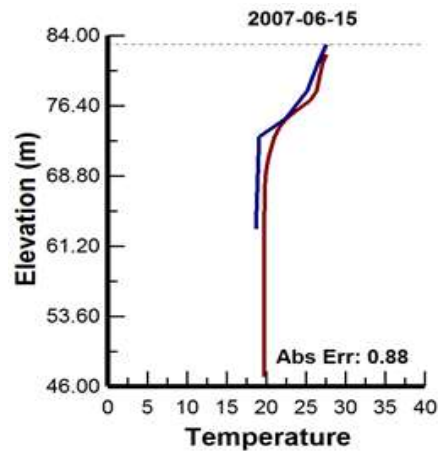
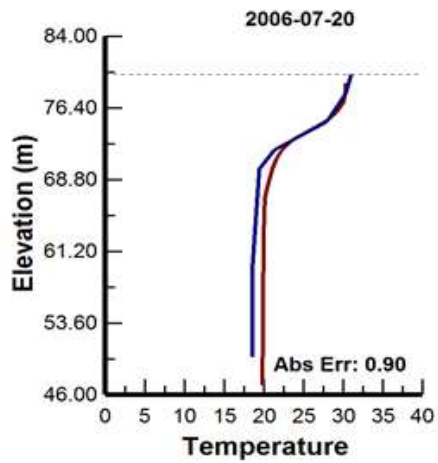
Temperature profiles

Calibration

— Observation

— Simulation

Validation



CE-Qual-W2, model performance Hsinshan Reservoir

Period	Metric	DO	SS	NH ₃ -N	NO ₃ -N	Chl-a	TP	ortho-P
		6 – 12 (mg/L)	(mg/L)	0 - 0.1 (mg/L)	(mg/L)	0 – 14 (µg/L)	0.01 – 0.04 (mg/L)	0 – 0.02 (mg/L)
2004- 2008	N	27	27	22	22	22	22	22
	AME	0.72	1.149	0.019	0.172	2.752	0.009	0.009
	RMSE	0.939	1.504	0.025	0.212	3.689	0.012	0.011
2009- 2012	N	30	30	16	16	16	16	16
	AME	1.123	1.632	0.021	0.348	2.186	0.01	0.007
	RMSE	1.494	2.064	0.026	0.371	2.919	0.012	0.008

Ensemble projected temperature change (TCCIP)

2020-2039

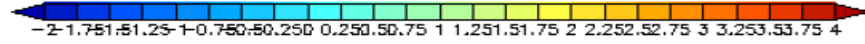
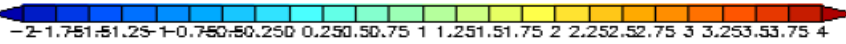
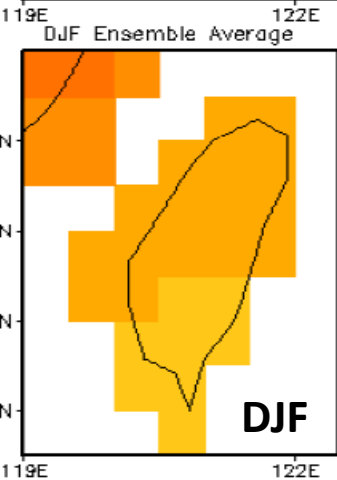
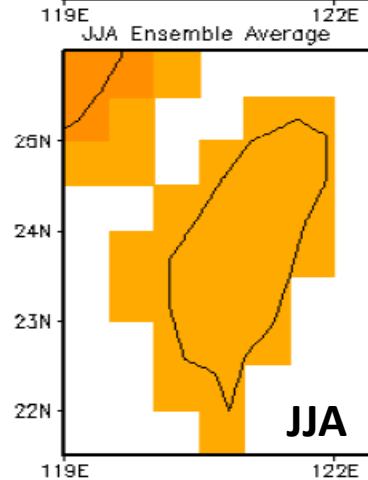
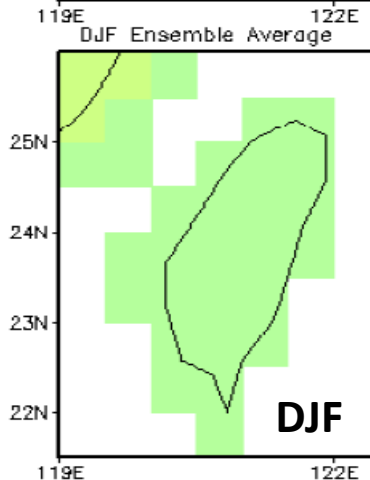
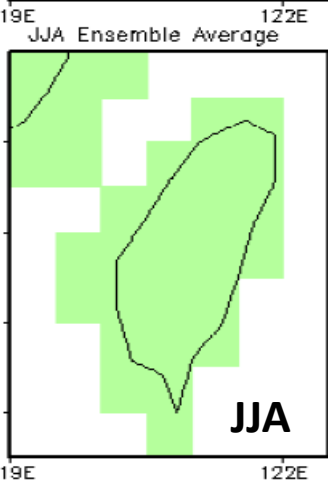
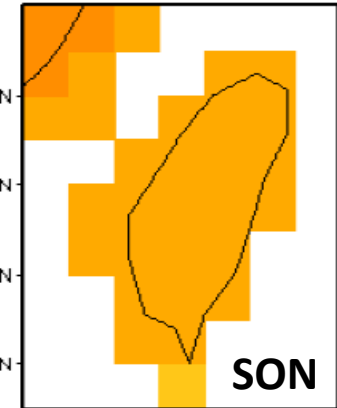
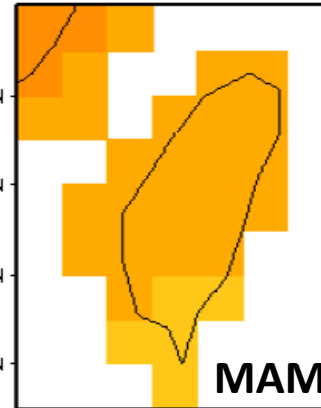
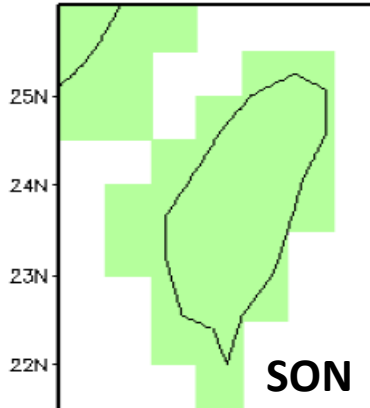
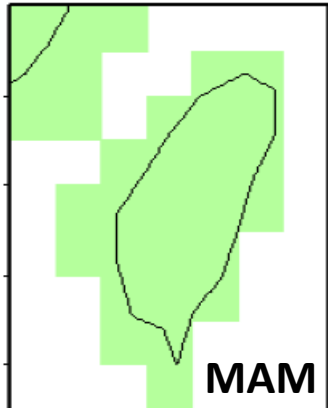
2080-2099

MAM Ensemble Average

SON Ensemble Average

MAM Ensemble Average

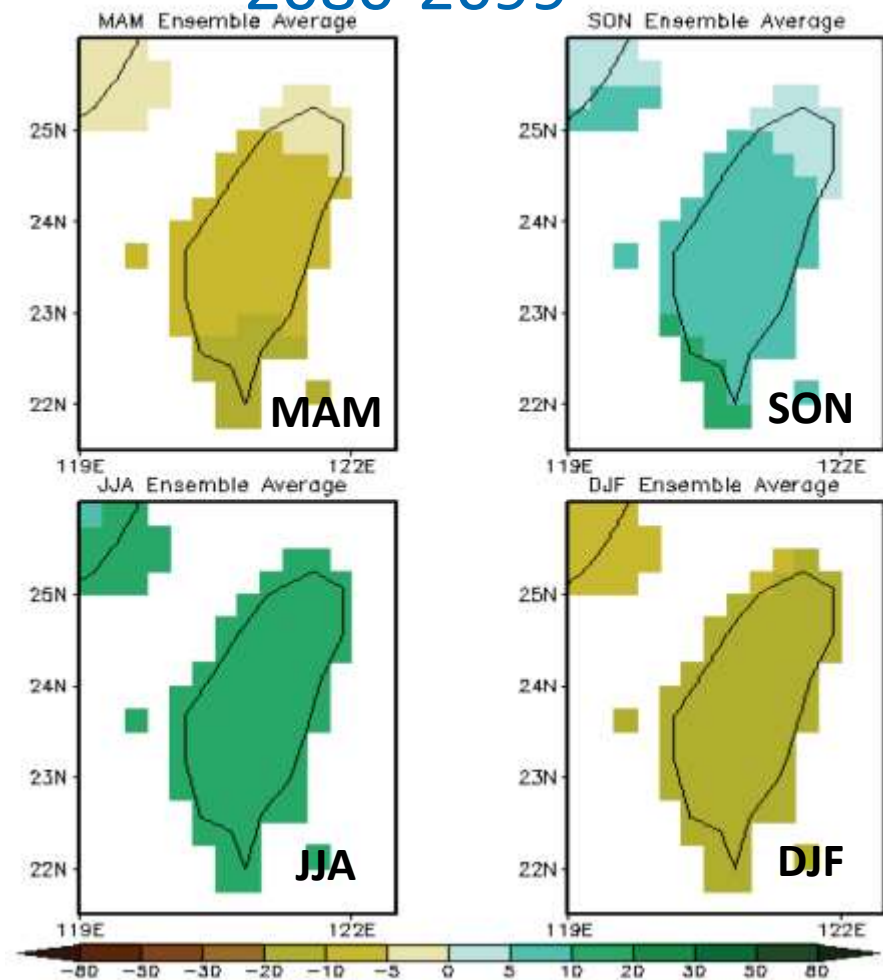
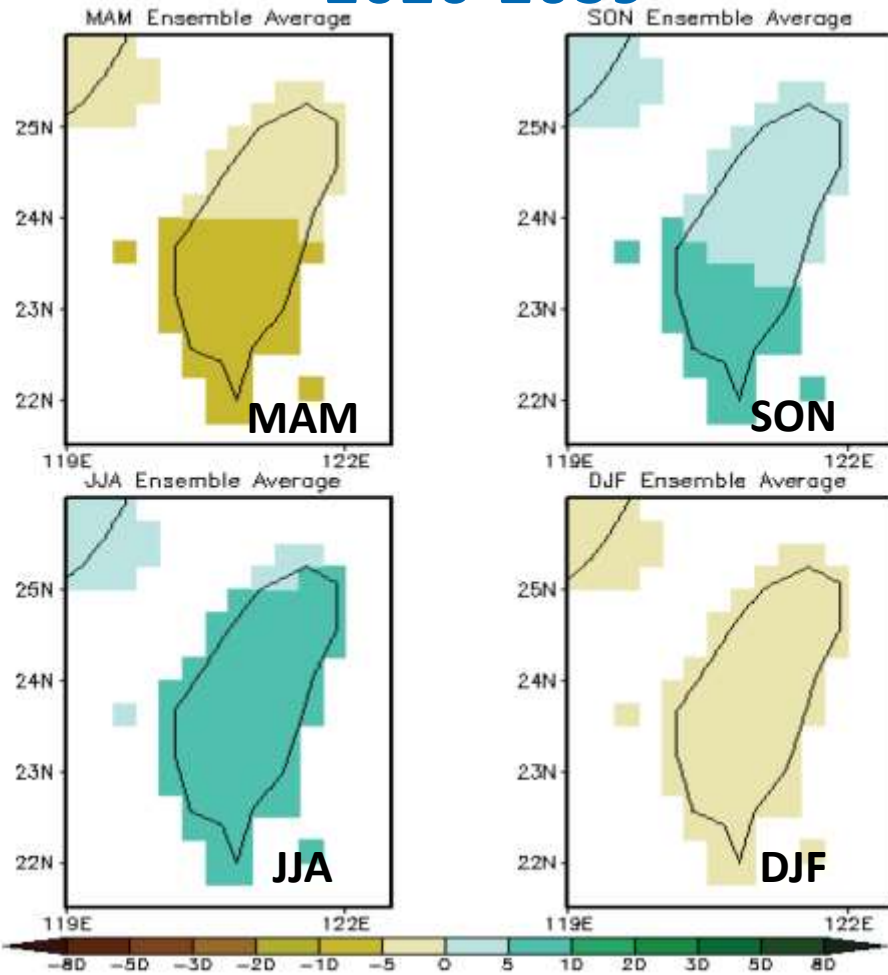
SON Ensemble Average



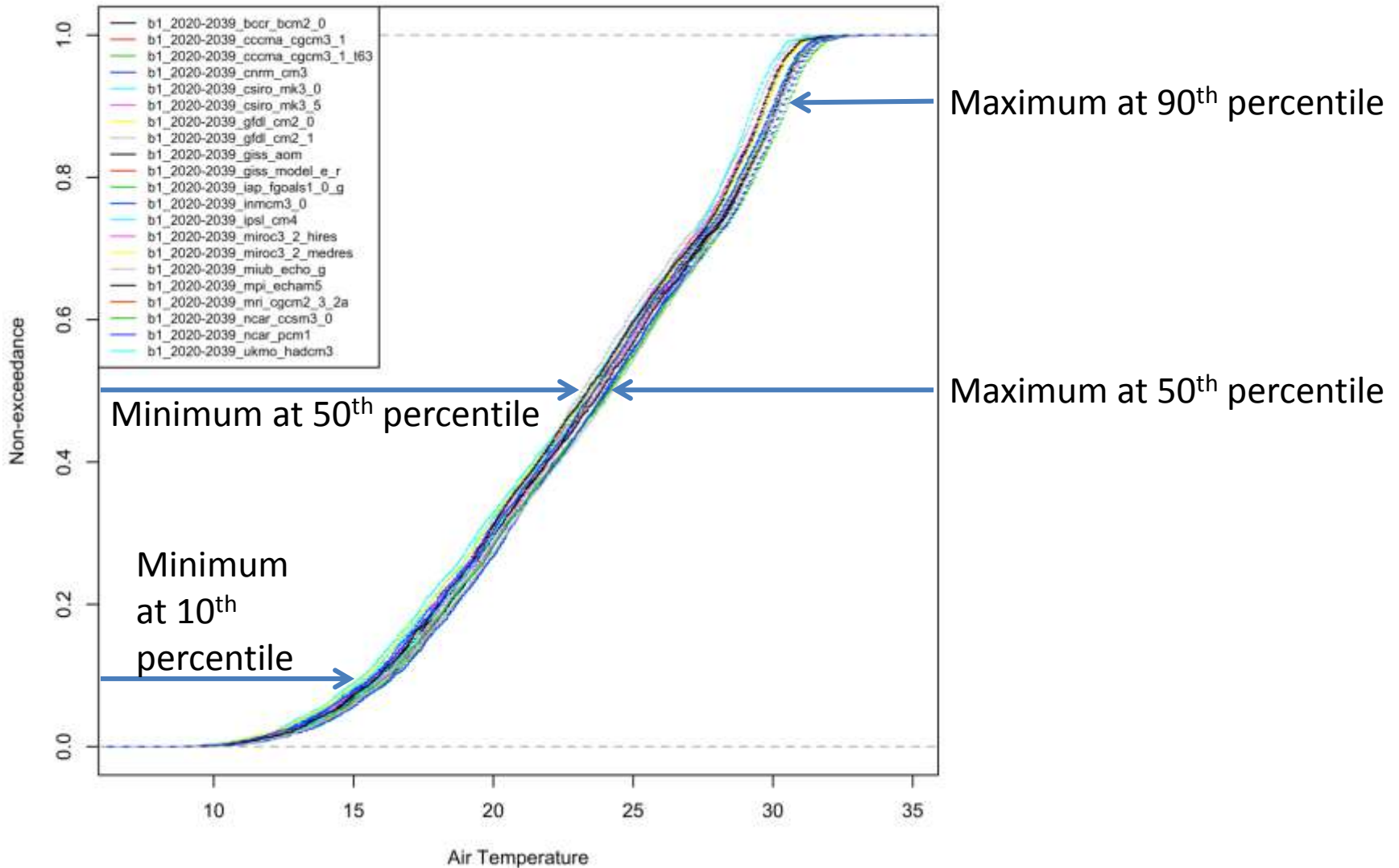
Ensemble projected precipitation change (TCCIP)

2020-2039

2080-2099



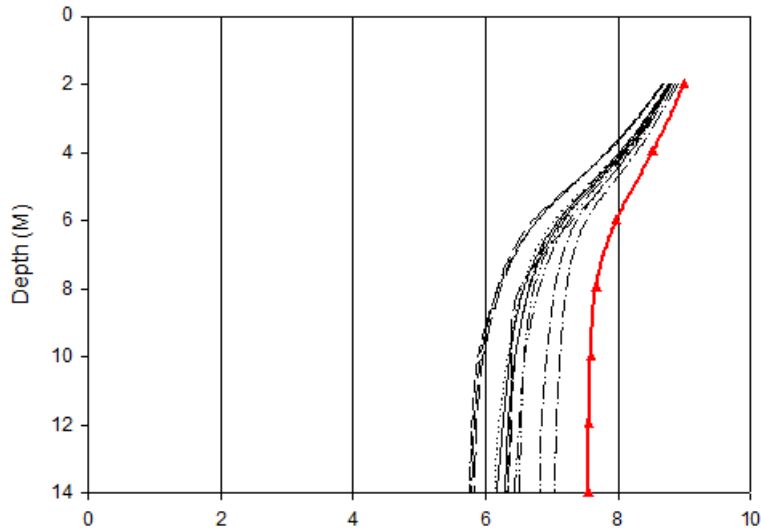
Individual Model Climate Scenarios - Air Temperature



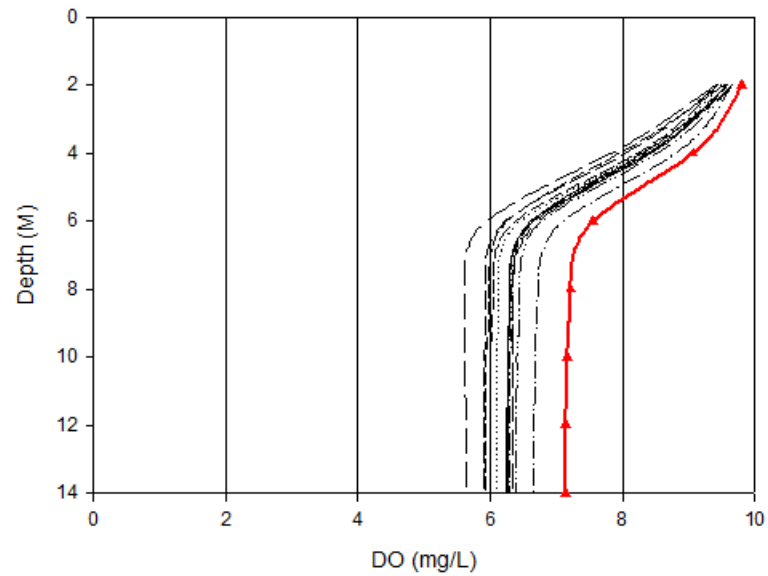
Average simulated temperature difference - surface and bottom of Hsinshan Reservoir

	2004-2012	2020-2039	2080-2099
Spring	3.13°C	3.16°C	3.53°C
Summer	10.84°C	10.85°C	11.59°C
Fall	6.59°C	6.62°C	7.61°C
Winter	0.62°C	0.62°C	0.94°C

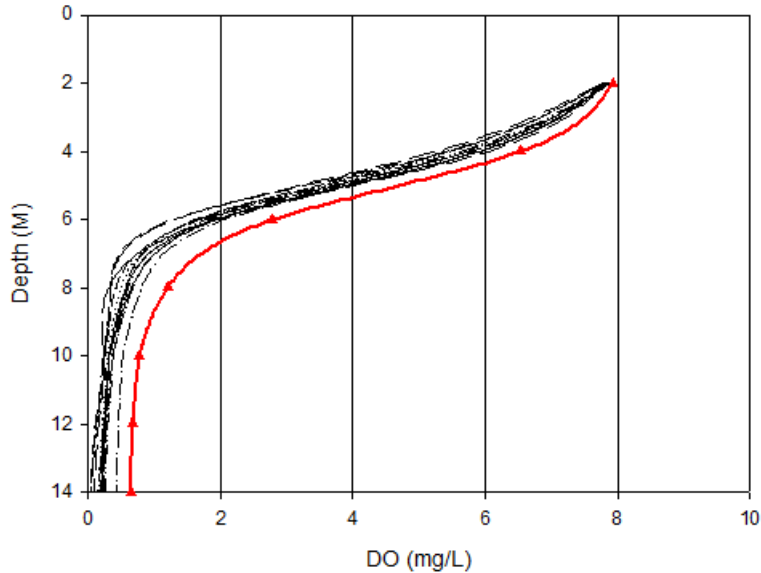
Winter - Profile of DO (2080-2099)



Spring - Profile of DO (2080-2099)

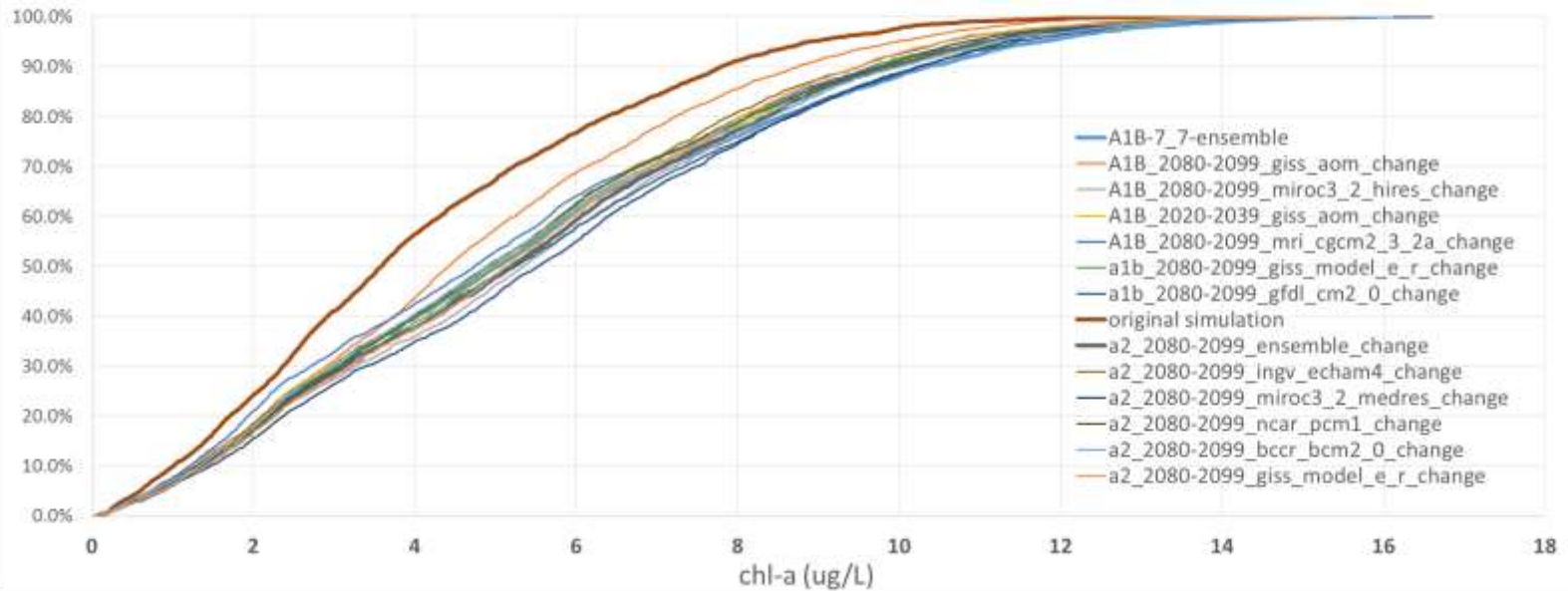


Summer - Profile of DO (2080-2099)



Dissolved Oxygen Profiles

Cumulative probability distribution (2080-2099)

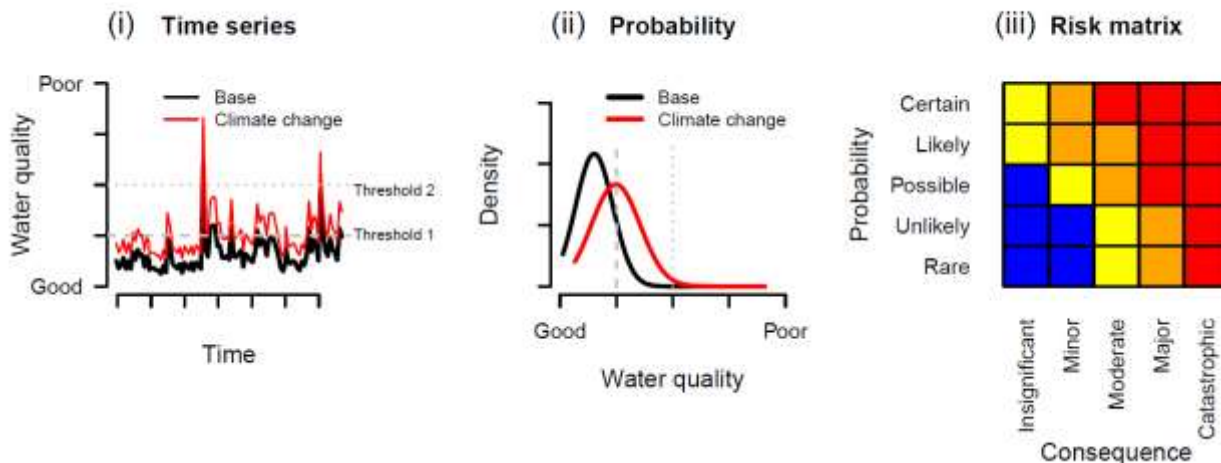


Conclusions

- Water quality trends projected are not catastrophic
- When phytoplankton groups are modelled
 - Total system response needs validation
- Existing management methods can probably cope with the chronic climate change trends observed here
 - Destratification
 - Hypolimnetic oxygenation
 - Nutrient management

Future Directions

- Integration with catchment models
- Real-time forecasting of riverine intrusions
- Comprehensive climate change scenarios
 - Quantify risks to water quality
 - Provide information for long term planning
- Model ensemble approach (Trolle et al. *Environmental Modelling & Software* 61 (2014) 371-379)



Brookes, J. D., Carey, C. C., Hamilton, D. P., Ho, L., van der Linden, L., Renner, R., & Rigosi, A. (2014). Emerging Challenges for the Drinking Water Industry. *Environmental Science & Technology*.

Acknowledgements

- Water Research Australia
- Water Research Foundation
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- Virginia Tech
 - John Little, Adil Godrej, Glen Moglen, Tom Grizzard,
- University of Western Australia
 - Matt Hipsey

