WP 4 – Assessment

Synthesis report on the usefulness of the WATExR tools for management and adaptation of water quality to climate extreme events across case studies

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1. Introduction

A key aim of the WATExR project is to develop user-friendly tools for seasonal forecasting of surface water quality and ecology, with a particular focus on lakes. The intention is for these tools to be useful to stakeholders to support water management. To develop the tools, seasonal climate model outputs were integrated with freshwater impact models (e.g. catchment hydrology and lake models) at four contrasting case study sites in Europe and Australia as described in D2.3. Tool development was done within a user-friendly software framework, designed together with stakeholders (D3.1 and D3.2).

WP4 of the WATExR project is aimed at assessing the usefulness of the seasonal forecasting tools developed for water management, as well as at identifying barriers and future opportunities for improvement. To assess the usefulness of the WATExR tools, two assessment tasks have been carried out at each case study site:

1) Assessment of usefulness of forecasting tools during a historic event: together with stakeholders, a historic season was chosen when an extreme seasonal climate event resulted in problems within the catchment/lake. Forecasts were then produced for this season, and stakeholders were asked (i) whether the forecasting tool would have been useful had it been available, (ii) if so, how their behaviour might have differed, and (iii) if not, what the key barriers are to usefulness.

2) Usefulness of “windows of opportunity”: The first assessment task, which focuses on a single historic event, may correspond with a season or variable which the forecasting system has little skill in at a given case study site, and so it is useful to carry out a more comprehensive assessment of which seasons and variables the forecasting systems have skill in (what we term “windows of opportunity”), and whether these are useful to water managers. The first part of this assessment task involves researchers identifying these windows of opportunity: a separate task in WP4 is to carry out a set of ‘re-forecasting’ experiments, where models are used to produce seasonal forecasts for a historic period and the skill of the forecasts is assessed (this exercise and associated results will be detailed in D4.3). Having identified windows of opportunity through this historic skill assessment exercise, stakeholders were presented with a summary of the results and asked to provide feedback on whether the windows of opportunity are useful to management.

This report is written in the form of a draft paper, and the aim is for it to be used as a working document during the remainder of the project. The final version of the deliverable will therefore contain a progress report for a number of case study sites, rather than final results. The final results will be added during the final year of the project.

The report is structured as follows: we describe the first historic event assessment task in a little more detail and present the outcomes of this task (Section 2). We then describe the second ‘windows of opportunity’ task, including a summary of the skilful variables/seasons identified, and stakeholder feedback on their usefulness (Section 3). We then provide a preliminary synthesis of results across case study sites in terms of commonalities and differences, key barriers and priorities for the future (Section 4).

2. Usefulness of WATExR tools during a historic extreme event

2.1 Event selection

Stakeholders at each case study site were asked to choose a historic season of interest which experienced prolonged extreme weather conditions (e.g. prolonged high temperatures and dry conditions, or a particularly wet season), and which was associated with problematic conditions in their surface water body of interest. The events chosen at each case study site are detailed in Table 1, together with management opportunities for mitigating the impact of the event, had a skilled forecast been available in advance.

Table 1. Historic seasonal climate events chosen at each site, and associated surface water impacts.

Case study site	Climate event	Surface water impacts	Management opportunities
Lake Vansjø, Norway	October-December 2000 was extremely wet. The lake level rose to unprecedented levels and flooded adjacent areas.	High nutrient inputs to the lake from agricultural runoff and flooding of sewage treatment/pumping stations. Algal blooms in the years following the flood (particularly from 2004), resulting in bathing bans in western parts of Lake Vansjø every summer from August 2001 until August 2007	The lake level is regulated and could have been lowered in advance of the wet season, reducing flooding of adjacent land and nutrient inputs. Farmers could be issued with management advice to reduce the chance of nutrient runoff.
Mount Bold Reservoir, Australia	Summer and Fall 2006 were drier than normal, and a water deficit built up because of a multi-year drought event with below average rainfall accumulations over 10 yrs (Millenium drought)	Elevated demand on supply – mitigated by demand reduction strategies. Lower reservoir level at beginning of ‘pumping season’. Low reservoir levels may result in some water quality problems.	In droughts, there are higher pumping costs of water and knowledge of anticipated rainfall and discharge into the reservoir would allow for strategic planning for pumping the water.
Sau Reservoir, Spain	Multiple floods occurred in October 2019 during the autumn season due to extreme precipitation events affecting the water quality variables in the reservoir for the rest of the season.	Unpredicted large water input with high organic matter content from the Ter River basin. The days preceding the event were very dry, so authorities were saving and storing water in Sau reservoir. When the torrential low-quality water arrived, it was still necessary to release good quality water downstream which led to an increase in treatment cost.	The lake level is regulated and could have been adjusted (lowered) in advance of the wet season, which would have reduced flooding of adjacent land, sediment loads and operational costs for water authorities.
Wupper Reservoir, Germany	June to August 2003 was one of the worst heatwaves that impacted Europe. The Wupper reservoir level had to be lowered substantially to continue supplying drinking water.	Low water level in the reservoir and high-water temperature for both surface and bottom layers, associated with constant nutrient loads from the upstream catchment present a risk of eutrophication. The reservoir has a bottom outlet; therefore it also impacts the downstream temperature and ecology.	The inflow of the reservoir is regulated via a series of reservoirs on the upstream sub-catchments, which gives an opportunity to store water in advance if a drought is expected.

2.2 Model forecasts for the events chosen

At each case study site, seasonal climate and catchment/lake forecasts were produced for the historic seasons selected by stakeholders as being of interest. Note that additional similar or adjacent seasons were also included in the analysis below for some of the case studies.

2.2.1 Seasonal climate forecasts

Within the operational WATExR tools, bias-corrected seasonal climate forecasts are generated from an ensemble (25 members) generated by the ECMWF's long-range forecasting system SEAS5 (Johnson et al., 2019). The ERA5 reanalysis (Hersbach et al., 2020) was used for bias correction of the SEAS5 data and taken as pseudo-observed data because of the lack of continuous observed data at some case study sites.

A summary of the seasonal climate forecast results for the historic events of interest for each site is given in Table 2, including forecasting skill information and observed weather for that season (the latter from ERA5). Seasonal climate forecasts are model predictions of how the weather will evolve over the next 3-6 months, and as day-to-day forecasts are unreliable over such long forecasting horizons, forecasts are instead used to look at whether the next 3-6 months will, on average, show broad differences to normal conditions. The forecasts in Table 2, and in the WATExR project more generally, are therefore provided in terms of the probability of weather variables falling into one of three terciles: below normal, normal or above normal. As seasonal forecasts are inherently probabilistic and uncertain, effective communication of forecast uncertainties is a vital part of the forecast. Reported forecasting skill information is made up of two parts: (1) information on the probability of the tercile, here given as the proportion of SEAS5 ensemble members which predicted the most likely tercile, and (2) information on how well the forecast performed during a historic assessment period. Here, we report the Receiver Operating Characteristic skill score (ROCSS). This is calculated for each weather variable, season and tercile and measures how well the forecast discriminates between binary events (whether the forecast correctly predicts observations occurring within the tercile). ROCSS values range from 1 (a perfect forecast) to -1 (a perfectly bad forecast). We chose to define forecasts as having historic skill when the ROCSS was significantly positive (i.e. the probability of obtaining this ROCSS was less than 5% under the assumption of no forecast skill). Non-significant ROCSS implies the modelling system has no skill compared to a random forecast.

Table 2. Relevant seasonal climate model forecast results for the historic events selected by stakeholders.

Site	Year, season (months in season)	Variable	Observed tercile (ERA5)[a]	Forecasted tercile[a]	Confidence in climate forecast		
					Tercile probability (%)[b]	Historic skill (ROCSS)[c]	Overall confidence[d]
Norway	2000, Late summer (Aug-Oct)	Precipitation	Above normal	Above normal	56	None (0.19)	None
		Temperature	Normal	Normal	60	None (0.23)	None
	2000, Early winter (Nov-Jan)	Precipitation	Above normal	Above normal	92	None (0.14)	None
		Temperature	Above normal	Above normal	68	None (0.22)	None

	2001, Early summer (May-Jul)	Precipitation	Below normal	Below normal	92	None (-0.38)	None
		Temperature	Normal	Above normal	40	None (0.15)	None
	2004, Early summer (May-Jul)	Precipitation	Normal	Below normal	48	None (-0.38)	None
		Temperature	Below normal	Below normal	64	None (0.15)	None
Australia	2006, Summer (Dec-Feb)	Precipitation	Normal	Below normal	40	None (-0.10)	None
		Temperature	Normal	Above normal	52	None (-0.43)	None
	2006 Autumn (Mar-May)	Precipitation	Above average	Normal	40	None (-0.12)	None
		Temperature	Below normal	Below normal	44	None (-0.09)	None
Spain	2019, Autumn (Sep-Nov)	Precipitation	Above normal	Above Normal	35	None (0.15)	None
		Temperature	Normal	Above Normal	75	None (0.05)	None
	2015, Autumn (Sep-Nov)	Precipitation	Above normal	Normal	35	None (0.29)	None
		Temperature	Normal	Above Normal	75	None (0.05)	None
Germany	2003 Summer (Jun-Aug)	Precipitation	Below normal	Above normal	55	None (-0.14)	None
		Temperature	Above normal	Above or Below normal	35	None (-0.61)	None

[a] One of Above normal, Normal, or Below normal
[b] Percent of SEAS5 members which forecasted the most probable tercile. To aid stakeholders in the interpretation of uncertainty, the probability of the tercile was discretized into four categories: Very low (<35%), Low (35-49%), Medium (50-64%) and High (65-100%)
[c] Assessed by comparing SEAS5 forecast with ERA5 observations for the period 1993-2019. ROCSS is the Receiver Operating skill score. Scores marked with an asterisk are significantly positive at 95% confidence level, and indicate that the system has significant skill for that variable, season and tercile.
[d] The forecast skill information was summarized into a single qualitative score, to aid stakeholders in the interpretation of overall confidence. The four following confidence classes were used: None, Low, Medium and High. Given that no ROCSS was significantly positive, none of the forecast was of any confidence.

Table 2 shows that the SEAS5 skills to forecast the meteorological events of interest to stakeholders is completely hindered by the absence of confidence. Indeed, the overall historic skills assessed by comparing the terciles forecasted by SEAS5 with those observed (ERA5) over each season within the period 1993-2019, were extremely low. In fact, the climate forecasts currently have no significant skill. Furthermore, SEAS5 forecasted in most cases a different tercile than the observed one with a probability ranging from low to high. Hence, in the case where these forecasts would have been available prior to the events of interest, the absence of confidence in the forecasts would have been a major limitation for any action to be taken by the stakeholders.

2.2.2 Catchment/lake water quality and ecology forecasts

The preliminary modelling workflow used at each site is described in detail elsewhere (e.g. Deliverables 2.3 and 3.1). Descriptions of the final operational workflows incorporated in each tool will accompany Deliverable 4.3. Lake model forecasts produced by the modelling workflows, driven using SEAS5 seasonal climate model output as input data, are given in Table 3. Associated forecast skill information and corresponding lake observations (where available) are also shown.

Table 3. Seasonal catchment/lake model forecasts for the historic events selected by stakeholders

Site	Year, season (months in season)	Variable	Observed class[a]	Forecasted class[a]	Confidence in forecast		
					Class probability (%)[b]	Historic skill[c]	Overall confidence[d]
Norway	2001 Summer (May-Oct)	Total P	Upper	Upper	Medium (63%)	Low (0.34)	Very low
		Chl-a	Upper	Upper	No estimate available	High (0.71)	Medium
		Colour	Upper	Lower	Medium (74%)	Medium (0.47)	Low
		Cyanobacteria	Lower[e]	Upper	Medium (64%)	High (0.78)	Medium
	2004 Summer (May-Oct)	Total P	Upper	Upper	Medium (68%)	Low (0.34)	Very low
		Chl-a	Upper	Lower	No estimate available	High (0.71)	Medium
		Colour	Upper	Upper	Medium (73%)	Medium (0.47)	Low
		Cyanobacteria	Upper	Upper	Medium (51%)	High (0.78)	Medium
Australia	2006, Summer (Dec-Feb)	Discharge Onkaparinga	Normal	None	Low (33%)	None (0.03)	Very low
		Discharge Echunga	Above	Normal	Medium (64%)	None (-0.02)	Very low
		Surface temperature	Below	Above	Low (48%)	None (-0.10)	Very low
		Bottom temperature	Above	Above	High (96%)	Low (0.29)	Low
		Water level	Above	Normal	Medium (68%)	None (0.11)	Very low
	2006 Autumn (Mar-May)	Discharge Onkaparinga	Above	Below	Low (44%)	None (-0.21)	Very low
		Discharge Echunga	Above	Below	Low (40%)	None (-0.01)	Very low

		Surface temperature	Below	Below	Low (40%)	None (0.19)	Very low
		Bottom temperature	Below	Above	High (100%)	None (-0.16)	Very low
		Water level	Above	Above	High (100%)	None (-0.06)	Very low
Spain	2019 Autumn (Sep-Nov)	Discharge	Above normal	Above normal	High (65%)	Medium (0.47)	Medium
		Gate III Temperature	No water level	No water level	No estimate available	High (0.96)	No estimate available
		Gate II Temperature	Above normal	Above normal	High (95%)	High (0.96)	High
		Gate I Temperature	Above normal	Above normal	High (100%)	High (1)	High
	2015 Autumn (Sep-Nov)	Discharge	Normal	Above normal	Medium (55%)	Medium (0.47)	Low
		Gate III Temperature	Below normal	Below normal	High (85%)	High (0.96)	High
		Gate II Temperature	Normal	Normal	High (75%)	High (0.96)	High
		Gate I Temperature	Above normal	Above normal	High (100%)	High (1)	High
Germany	2003 Summer (Jun-Aug)	Surface Temperature	Above normal	Normal/ Below normal	Low (35%)	None (-0.49)	Very low
		Bottom Temperature	Above normal	Above normal	High (95%)	High (0.83)	High

n.a.: not available

[a] In the Norwegian tool, two classes are forecasted for each variable, both linked to Water Framework Directive status classes. For simplicity, they are reported here as just 'Upper' (higher concentrations) and 'Lower' (lower concentrations). For the other sites, three classes were forecasted for each variable: Above normal, Normal, and Below normal.

[b] To aid stakeholders in interpreting the forecast spread between classes, and associated strength of the forecast, the class probability was discretized into categories: Very low (<25%), Low (26-50%), Medium (51-75%) and High (76-100%)

[c] An assessment of the historic skill score has been reported as the Matthew's correlation coefficient (MCC). The historic skill is summarized according to the following qualitative rules: None (MCC < 0.2), Low (MCC of 0.2-0.39), Medium (MCC of 0.4-0.59), High (MCC > 0.6)

[d] The forecast skill is summarized as a single qualitative score, to aid stakeholders in the interpretation of uncertainty. The following four classes were used: Very low, Low, Medium and High; The overall confidence was assessed as follows: if the class probability is "High", the overall confidence is the same as the historic skill, if the class probability is "Medium", then there is a lower confidence in the forecast. The overall confidence is the historic skill reduced by one class. For Chl-a, the confidence level is always Medium. Historic skill is High, but because of the lack of class probability information, it is reduced a level.

[e] Although the observed class was 'Lower', in fact toxic cyanobacterial blooms did occur in the lake near the popular bathing beaches, leading to bathing bans. These were not picked up by the lake monitoring point.

In general, Table 3 shows that water quality forecasts at all sites have at least some skill. The modelling workflows are thus more effective at forecasting the event in the lake, than the climate model at forecasting the climate event. Indeed, lake events are not only sensitive to climate in the target season but also to climate of previous season(s) due to storage time in the catchments and the lakes as well as other processes that are independent of climate, e.g., application of fertilizer by farmers. The very low historic skills reported for Mt Bold (Australia) can be attributed to the complexity of predicting the fluctuations in water level due to water pumping and to additional delivery water through the Murray Bridge pipeline into the Onkaparinga river. Observed data on the amount of water pumped from the reservoir and delivered through the Murray Bridge pipeline are limited to only a few years. An average annual cycle was calculated for both and replicated throughout the entire timeseries. While this assumption does not allow for inter-annual variation, it allowed for the simulation of seasonal water level fluctuations.

Forecasts of ecological variables (TOTP, chl-a, Colour, Cyanobacteria) generally have lower skills, with confidence ranging from very low to medium, than those for physical variables (Discharge and Temperature) which mainly have high overall confidence. This disparity reflects the added complexity and challenges in predicting ecological variables which are the result of complex interactions between physical, chemical and biological processes, in contrast to relatively simpler physical processes. Given the already significant skills of the water quality forecasts, we believe that, upon improvement of the seasonal climate forecasts, the seasonal water quality forecasts could become even more skilful.

2.3 Stakeholder feedback on forecasts

Seasonal climate and catchment/lake forecasts were presented to stakeholders in the form of screenshots or printouts of the WATExR tools for each site (see Appendix A). Stakeholders were involved in co-designing these tools and the layout used in each, and so were aware of how to interpret the skill and uncertainty information contained in them. Stakeholders were then asked to respond to a set of questions to assess the usefulness of the tools (Table 4). The first two questions were aimed at checking whether stakeholder perceptions of forecast reliability matched researcher perceptions; researchers were also asked to provide answers to these questions. The remaining questions dealt with the assessment of forecast usefulness. Stakeholder and researcher responses are provided in Table 5.

Table 4. Questions posed to stakeholders to assess tool usefulness. Researchers were also asked the first two questions.

Question
1. What is your interpretation of the seasonal climate forecast? (i.e. most likely outcome for the season of interest, and trustworthiness of the forecast)
2. What is your interpretation of the seasonal catchment/lake forecast? (i.e. most likely outcome for the catchment/lake variables that are included in the forecast, and the trustworthiness of the forecast)
3. Had these forecasts been available to you before the event of interest, would they have been useful to you?
4. If so, how might your behaviour have been different?
5. If not, why not? What are the key barriers to usefulness?
6. If the usefulness of the tools and forecasts was limited by uncertainty in the forecasts, what level of uncertainty would be acceptable for you to feel able to take action based on the forecast?

Table 5. Stakeholder perceptions on the usefulness of the seasonal climate and catchment/lake model forecasts for their chosen historic events. See Table 4 for the questions. For the first two questions, both stakeholders and researchers provided responses.

Site	Question	Response	
Norway	1	*Researcher:* The forecast does not have any skill in predicting the next season climate, as shown by the comparison between historical and forecasted climate.	*Stakeholder:* We are most interested to know if the next season will be really dry or wet. Are events with heavy rain likely? Will there likely be big floods? The temperature is also interesting. We could get a warning about the probability of a very hot season. We understand that the forecast is providing the information we are interested in, but for now, the is no confidence in this information.
	2	*Researcher:* The water quality forecast has some skill in predicting whether the variables of interest are predicted to be higher or lower than normal. However, the level of confidence is usually low, and the forecast use is limited and does not enable to forecast algae blooms, for example.	*Stakeholder:* We understand that water quality forecasts have some skill in predicting whether chl-a concentration is likely to be higher than normal, for example. However, we understand that the skill of the forecast is not enough to provide the probability of cyanobacterial bloom occurrence for example. Here are still hanging questions: Will there be blooms of cyanobacteria? Which WFD class can we expect? Colour might be interesting to MOVAR (drinking water supplier)
	3	No, I think the confidence is too low in this case to be useful.	
	4	not applicable	
	5	We need quite high confidence to act on the forecasts. If we can get predictions with high confidence about flooding episodes that will appear the next season, the power plant might be able to adjust the lake water level in advance.	
	6	I don't know, at least some confidence. The manoeuvring of lake Vansjø is complex due to the narrow outlet, and the operating procedures. But if we expected a big flood, we would have started a dialogue with the operators so they could act on the information.	
Australia	1	*Researcher:* The skill of the forecast is too low to make an accurate prediction for either of the climate variables.	*Stakeholder:* Given the low historic skill scores, find it difficult to see how I can recommend using these seasonal forecasts for any decision-making.
	2	*Researcher:* There is a medium probability that bottom temperatures will be higher than normal for the Mt Bold reservoir. The skill was too low in each of the other variables to make any accurate forecast.	*Stakeholder:* The confidence level of these forecasts is also low to very low and difficult to use. Something I find a little odd is the high probability (96%) of higher than normal bottom temperature given the low confidence.
	3	No, because I probably wouldn't have been able to convince anybody to trust them.	

	4	not applicable	
	5	With historic skills this low, they would not be used. We would just revert to scenario analysis or best guess strategies.	
	6	I think I would need to have probabilities and forecast confidences at the medium level before I would be willing to suggest alterations to operation or pumping strategies, etc.	
Spain	1	*Researcher:* Even there is no skill in the seasonal forecast data, it should be bias corrected and implemented in the impact models.	*Stakeholder:* We are interested in the key water quality variables used for water treatment in our plan. So independent of the direct usefulness of the seasonal forecast data, some skill found from the impact models could be useful.
	2	*Researcher:* There is some skill after hydrological modelling and significant skill after lake modelling.	*Stakeholder:* the skilful water quality variables found could allow us to have an additional tool to take decisions.
	3	It could have been useful, but I wouldn't trust them, at least not in the first times.	
	4	I could have talked with my team, show them the results and ask for their opinion, but we would have taken the decision as usual. We would have tried the tool many times after being sure or not that it's a trustworthy additional information.	
	5	not applicable	
	6	No answer yet from stakeholder.	
Germany	1	*Researcher:* The forecast has very low skills in predication for all of the relevant climate variables.	*Stakeholder:* Our main interest is to forecast whether the next season will be really dry or wet. i.e. events with heavy precipitation and occurrence of floods as well as the temperature and an assessment of the draughts and heat waves. However, due to the very low skill of the seasonal forecasting, such indices will not be considered.
	2	*Researcher:* The skill of the forecast for bottom temperature over the summer season is remarkably high and seems consistent over the years, while the skill for surface temperature was very low. However, the temperature of the bottom layers in the summer season is highly impacted by the previous season's legacy. Therefore, the high skill in the bottom layers cannot be used as an indicator of a single climate event. A prediction for the summer season should thus be taken with caution unless the interest is in the bottom layers to predict water quality withdrawn through the bottom outlet.	*Stakeholder:* One of the Wupper reservoir's main purposes is the regulation of the water temperature downstream of the dam. The water is being with-drawn through two openings at the bottom of the reservoir. The fact of the high skill on the predicted water temperature in the bottom layer at the outlet of the Wupper reservoir can be considered as useful information as far as this role of the reservoir is concerned. Decisions regarding the entire reservoir (e.g., Flood control, recreation purposes) cannot be taken considering that high skills were only associated to the bottom water temperature.
	3	It is of extreme importance to have an idea about the next season. However, due to the low skill of the climate forecasting it is difficult to have	

		confidence. Moreover, the skills for surface temperature and for discharge are very low, while that for bottom temperature is high. The limited predictability, in turn, makes it challenging to develop corresponding reservoir management strategies ahead.
	4	Strategies considering the quantity of the withdrawn water downstream to regulate the water temperature could be developed. However, the lack of reliable information considering the entire reservoir (water volume and storage capacity) and catchment does not support a holistic strategic approach.
	5	not applicable
	6	It is essential to have significant skill over the entire water column to consider the usefulness of the tool. Having low forecasting skills for climate and for surface water temperature does not support relevant decision making.

Table 5 shows that the interpretation of the forecasts by researchers and stakeholders are fairly consistent. Both parties show a similar level of understanding of the forecasts, associated uncertainties and confidence level. While some researchers emphasize the potential applicability of the climate forecasts within the modelling workflow, the stakeholders see its potential use for decisions making. Given the absence of skills for the climate forecasts, we can also notice some disappointment about the low level of confidence which was usually described as the main barrier to the tools' usefulness.

2.4 Summary of usefulness of tools during selected historic events

In general, stakeholders were enthusiastic about the tools at the beginning and more sceptical after the exercise due to the low confidence in forecasts. However, some of them were surprised about the relatively high level of confidence. All stakeholders were highly interested in the water quality forecasts and most of them show also a high interest for climate forecasts. However, they are well aware of the limited skills of the forecasts and the restricted confidence level.
Many stakeholders identified actions that could have helped reduce the negative impacts of the selected events. Nevertheless, stakeholders stated that the climate forecasts would be currently ignored in their decision process due to the absence of confidence, and they are still a bit septic in directly using the water quality forecasting tool without rigorous testing beforehand for decision making. Still, stakeholders express some optimism about the tools' expected value with increasing climate forecasting skills in the near future.

3. Identification of "windows of opportunity" and assessment of their usefulness

As mentioned in the introduction, the first assessment task, which focuses on whether forecasts were useful for a single historic event per case study site, has limited focus. By just considering a single season and in some cases only one or two forecasted variables, the assessment of whether tools were useful may look unduly negative if the event happened to coincide with a season or variable which the forecasting system has little skill in. Here, we therefore present a more comprehensive assessment of which seasons and forecasted variables the WATExR tools have skill in (what we term "windows of opportunity"). These windows of opportunity were then assessed by the co-developers at each site, in terms of whether they considered them potentially useful for water management.

3.1 Windows of opportunity identified through 're-forecasting'

The first part of this assessment task involves the researchers at each case study site identifying those variables, seasons and terciles/classes for which their forecasts had skill. This was assessed through a 're-forecasting' or hindcast experiment, where impact models were used to produce seasonal forecasts for a historic period (as a minimum 1993-2019, in some cases longer) and the skill of the forecasts was assessed by comparing to meteorological or lake observations. The details of this 're-forecasting' experiment will be presented separately in D4.3. Here, we present just the 'windows of opportunity' that were identified.

Table 6 summarises the windows of opportunity for the SEAS5 climate forecasting system, in terms of the meteorological variables which had some skill during particular seasons and terciles (as assessed using ROCSS scores, see Section Seasonal climate forecasts). Overall, we can see that SEAS5 had low skill at all sites for almost all variables, seasons and terciles. The few skilful combinations were spurious significances given that less than 5% of all combinations were skilful at all case studies except Australia. In addition, most of the windows of opportunity included a season or a variable that was not of interest for the stakeholders.

Table 6. Climate variables, seasons and terciles for which SEAS5 has significant positive ROCSS scores, as assessed by comparison to ERA5 data over the period 1993-2019.

Site	Number of skilful /total combinations[a]	Skilful climate variable/season/tercile combinations		
		Variable[b]	Season	Tercile
Norway	2/108	rsds	Early summer (months 5-7)	Upper
		uas	Winter (months 11-1)	Middle
Australia	9/108	psl	Summer (months 12-2)	Upper
			Spring (months 9-11)	Upper
		cc	Winter (months 6-8)	Middle
			Spring (months 9-11)	Upper
		tdps	Summer (months 12-2)	Upper
		rlds	Autumn (months 3-5)	Upper
		tas	Spring (months 9-11)	Middle
		rsds	Spring (months 9-11)	Upper
		petH	Spring (months 9-11)	Upper
Spain	5/108	cc	Spring (months 3-5)	Upper
			Summer (months 6-8)	Upper
			Autumn (months 9-11)	Upper
		psl	Spring (months 3-5)	Upper
		tdps	Summer (months 6-8)	Upper
Germany	3/96	tdps	Spring (months 3-5)	Upper
		rlds	Winter (months 12-2)	Middle
		vas	Winter (months 12-2)	Lower

[a] For all case studies except Wupper (Germany), ROCSS scores were calculated for 108 data 'slices' in total: 9 met variables x 4 seasons x 3 terciles. For Wupper, scores for only 8 met variables were calculated

[b] Met variables are abbreviated as follows: psl: surface pressure, tcc: total cloud cover, uas: 10 m U wind component, vas: 10 m V wind component, tas: 2 m temperature, tdps: 2 m dewpoint temperature, rsds: downwards surface solar radiation, rlds: downwards surface thermal radiation downwards, tp: total precipitation.

Table 7. Catchment/lake variables, seasons and classes for which seasonal surface water forecasts had skill, as assessed by comparison to surface water observations from the catchment/lake.

Site	Number of skilful /total combinations[a]	Catchment/ lake variable	Season	Class	Historic assessment period	Statistic(s) used in assessment of historic skill
Norway	9/36	Discharge	Spring	Lower, Upper	1994-2016	ROCSS
		Surface temperature	Winter	Lower		
			Spring	Lower, Upper		
		Bottom Temperature	Winter	Lower, Upper		
			Spring	Lower, Upper		
Norway[b] (water quality)	8/8	Total P	Summer (the only season simulated)	Lower, Upper	1981-2019	Matthew's correlation coefficient, Pearson's r, RMSE, ROCSS
		chl-a				
		Colour				
		Cyanobacterial biovolume				
Aus-tralia	1/36	Echunga Discharge	Spring	Lower	1993-2016	ROCSS
Spain	26/36	Discharge	Summer	Lower	1988-2020	ROCSS
			Autumn	Upper		
			Winter	Normal		
		Temperature 5m	Spring	Lower, Normal, Upper		
			Summer	Lower, Upper		
			Autumn	Lower, Normal, Upper		
			Winter	Lower, Normal, Upper		
		Temperature 15m and 30 m	Spring	Lower, Normal, Upper		
			Summer	Lower, Normal, Upper		
			Autumn	Lower, Normal, Upper		
			Winter	Lower, Normal, Upper		
Germany	8/36	Surface Temperature	Autumn	Upper	1994-2016	ROCSS
		Bottom Temperature	Spring	Lower, Upper		
			Summer	Lower, Normal, Upper		
			Autumn	Lower, Upper		

[a] For all case studies, ROCSS scores were calculated for 36 data 'slices' in total: 3 impact variables x 4 seasons x 3 terciles.
[b] For Vansjø (Norway), scores for 4 additional water quality impact variables for only one season (Summer) and two classes were calculated (see also Table 3).

The windows of opportunity for forecasted catchment/lake water quality and ecology variables are summarised in Table 7 for each case study site. Except for the Australian case study, there is a larger number of variables showing some skill compared to the climate forecasts, reflecting variable amounts of model insensitivity to meteorological conditions during the target season due to storage time in the catchments and lakes. In particular, the bottom temperature forecasts are more often skilful compared to the other physical variables probably indicating a higher degree of inertia for hypolimnetic waters. The absence of windows of opportunity for the Australian case study likely reflects the complexity of predicting the fluctuations in water level due to unknown water pumping and delivery patterns as discussed above.

3.2 Stakeholder feedback on how useful the windows of opportunity for skilful seasonal forecasts are for water management

Stakeholders were presented with a summarised version of the windows of opportunity identified, targeted to their interests (Table 8). They were then asked to respond to a set of questions (Table 9) and provide feedback on whether they envisaged these windows of opportunity being useful to them in terms of management. Responses are given in Table 10. In summary, the stakeholders found many of the windows of opportunity useful for them as a complementary tool to plan preventive measures and manage resources before expected events. They also identified a few other potential windows of opportunity if the climate forecasts were more skilful and were quite optimistic about future implementation of the operational tools.

Table 8. Summary presented to stakeholders of the variables, seasons and conditions under which the forecasts are most likely to have skill. This summary was targeted to the interests of the stakeholders at each case study site, and so may not include all the ‘windows of opportunity’ identified in Section **Windows of opportunity identified through ‘re-forecasting’**.

Case study site	Summary of windows of opportunity presented to stakeholders
Norway	• The seasonal forecast has no skill at predicting most of climate variables • The forecast has some skill at predicting discharge, bottom and surface water temperature as well as concentrations of total P, colour, chl-a, and cyanobacterial biovolume in the lake
Australia	• The seasonal forecast has no skill at predicting most of climate variables • The forecast has few skills at predicting discharge in the river basin and no skill at predicting water temperature in the reservoir
Spain	• The seasonal forecast has no skill at predicting most of climate variables • The forecast has few skills at predicting discharge in the river basin and significant skill at predicting water temperature in the reservoir
Germany	• The seasonal forecast has no skill at predicting most of climate variables • The seasonal forecast has no skill at predicting inflow from the catchment or res-ervoir surface temperature • The lake model forecast has had a significant skill at predicting water bottom temperature in the reservoir

Table 9. Questions posed to stakeholders to assess the usefulness of the windows of opportunity.

Questions
1. Will any of the 'windows of opportunity', where the model forecast may be skilful, be useful to you for management? If so, which ones?
2. If so, how might you manage the catchment/lake differently? Be as specific as possible.
3. If you don't see use from the identified 'windows', what would your top priority be for a future skilled forecast variable/season?

Table 10. Stakeholder assessments of whether the windows of opportunity identified for their case study site may be useful to management.

Case study site	Stakeholder response
Norway	1. It will be useful to know in the advance if there is a risk of alga blooms and high levels of microcystin. The prediction of chl-a and cyanobacterial biovolume levels are the most useful in that respect. Colour can also be useful for the drinking water suppliers. 2. With the chl-a and cyanobacterial biovolume forecasts, the municipalities can be better prepared how to act if it is necessary to prevent people from bathing, prepare for another regime for water samples and give people good information. In the case of a high probability of algae blooms for example, it may be appropriate to increase the sampling frequency in the lake. Colour forecasts will also be useful to MOVAR which produces drinking water from Lake Vansjø in four municipalities for about 75 000 inhabitants. Regarding operation/production of drinking water, we can plan resource use and staffing. For example, if we had been notified in advance of extreme colour level, this would have exceeded production capacity and sludge production. We would have needed more staff on weekends to drain sludge. 3. If the climate forecasts were skilful, we would see a few other windows of opportunity. For example, when the summer is forecasted to be very wet or very dry, we could notify authorities controlling the manoeuvring of Vansjø. If there is a high confidence that flooding episodes will occur during the next season, the power plant might be able to adjust the water level in the lake in advance. It may also be possible to use the weather forecasts for the coming season to alert or motivate farmers to make the right agronomic choices, for example in extreme drought, floods or heavy rainfall. For example, it is difficult to harvest grain in very dry autumn, it is useless to fertilize during very wet fall. Climate forecasts may be important for the choice of seed or type of vegetable that should be grown. For example, barley should be avoided if next summer is predicted to be very wet. Some measures, such as hydrotechnical measures, may be most beneficial to perform in dry weather, to retain water for irrigation. However, even with high confidence climate forecasts, there will a certain risk for taking measures in advance, so these practices must be at the farmer's own responsibility.
Australia	No answer yet from stakeholder
Spain	1. We found the report useful for us because, even if we continue to make the decisions based on expert knowledge, it could help us to technically support the management in the reservoirs. 2. The management becomes sometimes very difficult and we had to take reactive decisions day by day according to the behaviour of the reservoir and expert knowledge, the tool could help us to take more proactive decisions. 3. Since we don't see a window of opportunity from the seasonal forecast in the next year, but we still can obtain useful results from the impact model, we would like to have an additional exercise which runs the workflow using climatological data to test if maybe we could have forecast results from the river and lake independent of the climatic data. We also are aware

	that these seasonal forecast systems could be improved in the future and we could have a better resource and a developed workflow.
Germany	1. It is of major importance to have information regarding bottom as well as surface temperature. Forecasting of other water quality variables such as algae biomass and dissolved oxygen would also be helpful to provide a more holistic picture. Having the opportunity to be provided with reliable information regarding all the parameters mentioned above combined with the observed past meteorological conditions can be the basis of a strategy framework concerning the downstream water temperature regulation and the maintenance of specific requirements for the recreational purposes of the reservoir. 2. The management of the released outflow and in extension the water temperature downstream, as well as the inflow regulation and maintenance of the water quality in the reservoir demand a holistic overview of the hydrological system. The tool could help visualise future extreme scenarios and develop various strategies according to set thresholds. 3. In case there is no use for the identified "windows", top priority would be to check the signal of the previous consecutive seasons. If the previous consecutive seasons have been dry, there is a higher risk of water scarcity in the catchment and further in the reservoir. The knowledge concerning possible drought periods in the coming season, based on skilled seasonal forecasting, will be very helpful to react with effective mitigating risk measures via improved management strategies of the reservoir system.

4. Synthesis across case study sites: opportunities and barriers

Stakeholders expressed their enthusiasm with respect to the presented tools and found them useful in general, although the low confidence scores for most of the forecasts would have prevented them to take any major preventive action. Some of the stakeholders consider the tools as useful add-ons into their existing decision-making resources. Potential usefulness of the forecasting tools is highly limited by the absence of skills for climate forecasts. The low skills of climate forecasts thus represent the main barrier to the successful implementation of the operational forecasting tools for water management.

In terms of windows of opportunity, the climate forecasts showed a small number of skilful variable/season/tercile combinations ranging from 2 to 9 skilful combinations out of 96-108 (Table 6). Hence the vast majority of the climate forecasts have no significant skill at the study sites. Note that the Australian case showed the highest number of skilful climate forecasts as expected since the climate in the adjacent regions is more predictable than over Europe (Manzanas et al., 2014). On the other hand, a higher number of impact variable forecasts showed significant skills for the three European case studies but only one impact variable forecast had significant skill at the Australian case study (Table 7). This disparity among the European sites and the Australian site highlights the added value of the impact models, if enough observed data are available for calibration. Indeed, the low skills of the Australian impact variable forecasts are likely related to the absence of data on artificial water pumping and delivery.

In summary, the provision of these forecasting tools to stakeholders generated fruitful interactions. These now established profitable connections between water quality experts and stakeholders offer a high potential for rapid implementation of an integrated operational forecasting workflow, from climate forecasts to the decision processes. Hence, upon skill improvement of the climate forecasts, a small step would be needed to achieve trustful preventive actions for better water management.

5. References

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Appendix A: Forecasts presented to stakeholders

At each case study site, stakeholders chose a historic season and then the WATExR tools were used to produce seasonal forecasts for that historic season. These forecasts are reproduced below. Note that additional seasonal forecasts for similar or adjacent seasons were also included below for some of the case studies.

Norway's Forecasts

Seasonal forecast of climate

Forecast for Lake Vansjø for late summer 2000. Forecast issued 10th July 2000

This page shows temperature and precipitation conditions expected for south-eastern Norway during the next three months. For summer (May-Oct), lake water quality forecasts for the western basin of Lake Vansjø (Vanemfjorden) are also produced, to predict ecological status according to the Water Framework Directive.

Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
April	Summer water quality Early summer climate	May - October May - July
July	Late summer climate	August - October
October	Early winter climate	November - January
January	Late winter climate	February - April

Forecasts are issued by NIVA as part of the ERA4CS-funded WATExR project

Climate forecast for August 2000 – October 2000

A guide to interpreting seasonal climate forecasts accompanies this bulletin.

Temperature

Tercile	Probability	Historic skill*	Forecast summary
Cooler than normal	Very low (0%)	None	Forecast confidence is **too low** to make temperature predictions for the coming season
Normal	Medium (60%)	None	
Warmer than normal	Low (40%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Precipitation

Tercile	Probability	Historic skill*	Forecast summary
Drier than normal	Very low (16%)	None	Forecast confidence is **too low** to make precipitation predictions for the coming season
Normal	Very low (28%)	None	
Wetter than normal	Medium (56%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Confidence score guide used to generate forecast summary*

Probability of the tercile	Historic skill	Confidence that tercile will happen	Confidence that tercile won't happen
Very low (less than 35%)	Some (significant ROCSS)	Very low	High
Low (35% - 50%)		Low	Medium
Medium (50% - 65%)		Medium	Low
High (65% or more)		High	Very low
Any value	None (insignificant ROCSS)	None	None

*See accompanying guide “Understanding and interpreting seasonal climate forecasts” for more details

Seasonal forecast of climate

Forecast for Lake Vansjø for early winter 2000. Forecast issued 10th October 2000

This page shows temperature and precipitation conditions expected for south-eastern Norway during the next three months. For summer (May-Oct), lake water quality forecasts for the western basin of Lake Vansjø (Vanemfjorden) are also produced, to predict ecological status according to the Water Framework Directive.

Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
April	Summer water quality Early summer climate	May - October May - July
July	Late summer climate	August - October
October	Early winter climate	November - January
January	Late winter climate	February - April

Forecasts are issued by NIVA as part of the ERA4CS-funded WATExR project

Climate forecast for November 2000 – January 2001

A guide to interpreting seasonal climate forecasts accompanies this bulletin.

Temperature

Tercile	Probability	Historic skill*	Forecast summary
Cooler than nor-mal	Very low (8%)	None	Forecast confidence is **too low** to make temperature predictions for the coming season
Normal	Very low (24%)	None	
Warmer than nor-mal	High (68%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Precipitation

Tercile	Probability	Historic skill*	Forecast summary
Drier than normal	Very low (0%)	None	Forecast confidence is **too low** to make precipitation predictions for the coming season
Normal	Very low (8%)	None	
Wetter than nor-mal	High (92%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Confidence score guide used to generate forecast summary*

Probability of the tercile	Historic skill	Confidence that tercile will happen	Confidence that tercile won't happen
Very low (less than 35%)	Some (significant ROCSS)	Very low	High
Low (35% - 50%)		Low	Medium
Medium (50% - 65%)		Medium	Low
High (65% or more)		High	Very low
Any value	None (insignificant ROCSS)	None	None

*See accompanying guide "Understanding and interpreting seasonal climate forecasts" for more details

Seasonal forecast of climate and lake water quality

Forecast for Lake Vansjø for (early) summer 2001. Forecast issued 10th April 2001

This page shows temperature and precipitation conditions expected for south-eastern Norway during the next three months. For summer (May-Oct), lake water quality forecasts for the western basin of Lake Vansjø (Vanemfjorden) are also produced, to predict ecological status according to the Water Framework Directive.

Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
April	Summer water quality Early summer climate	May - October May - July
July	Late summer climate	August - October
October	Early winter climate	November - January
January	Late winter climate	February - April

Forecasts are issued by NIVA as part of the ERA4CS-funded WATExR project

Climate forecast for May 2001 – July 2001

A guide to interpreting seasonal climate forecasts accompanies this bulletin.

Temperature

Tercile	Probability	Historic skill*	Forecast summary
Cooler than nor-mal	Very low (32%)	None	Forecast confidence is **too low** to make temperature predictions for the coming season
Normal	Very low (28%)	None	
Warmer than nor-mal	Low (40%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Precipitation

Tercile	Probability	Historic skill*	Forecast summary
Drier than normal	High (92%)	None	Forecast confidence is **too low** to make precipitation predictions for the coming season
Normal	Very low (8%)	None	
Wetter than nor-mal	Very low (0%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Confidence score guide used to generate forecast summary*

Probability of the tercile	Historic skill	Confidence that tercile will happen	Confidence that tercile won't happen
Very low (less than 35%)	Some (significant ROCSS)	Very low	High
Low (35% - 50%)		Low	Medium
Medium (50% - 65%)		Medium	Low
High (65% or more)		High	Very low
Any value	None (insignificant ROCSS)	None	None

*See accompanying guide “Understanding and interpreting seasonal climate forecasts” for more details

Lake chemistry and ecology forecast for May 2001 – October 2001

Lake water quality forecasts are for the western basin of Lake Vansjø (Vanemfjorden) and aim to predict ecological status according to the Water Framework Directive (WFD). A guide to interpreting these forecasts accompanies this bulletin.

Total phosphorus (growing season mean)

<table>
<tr><th rowspan="2">WFD class</th><th rowspan="2">Probability of class</th><th rowspan="2">Forecasted value (µg/l)</th><th colspan="3">Historic skill*</th><th rowspan="2">Forecast summary</th></tr>
<tr><th>RMSE[1]</th><th>Classification error (%)[2]</th><th>MCC[3]</th></tr>
<tr><td>Upper Moderate or better (< 29.5 µg/l)</td><td>Low (37%)</td><td rowspan="2">30.6</td><td rowspan="2">3.9</td><td rowspan="2">33</td><td rowspan="2">0.34</td><td rowspan="2">TP is expected to be lower Moderate or worse.
Confidence level: Very low</td></tr>
<tr><td>Lower Moderate or worse (≥ 29.5 µg/l)</td><td>Medium (63%)</td></tr>
</table>

*Click here for a plot summarising historic skill

Chlorophyll-a (growing season mean)

<table>
<tr><th rowspan="2">WFD class</th><th rowspan="2">Forecasted value (µg/l)</th><th rowspan="2">Predicted class[a]</th><th colspan="3">Historic skill*</th><th rowspan="2">Forecast summary</th></tr>
<tr><th>RMSE[1]</th><th>Classification error (%)[2]</th><th>MCC[3]</th></tr>
<tr><td>Moderate or better (< 20 µg/l)</td><td rowspan="2">22.2</td><td rowspan="2">Poor or worse</td><td rowspan="2">4.6</td><td rowspan="2">11</td><td rowspan="2">0.71</td><td rowspan="2">chl-a is expected to be Poor or worse.
Confidence level: Medium</td></tr>
<tr><td>Poor or worse (≥ 20 µg/l)</td></tr>
</table>

[a]A simpler forecasting model was used for chl-a (see accompanying guide), so no class probabilities are available.
*Click here for a plot summarising historic skill

Cyanobacteria (growing season maximum)

<table>
<tr><th rowspan="2">WFD class</th><th rowspan="2">Probability of class</th><th rowspan="2">Forecasted value (mm³/l)</th><th colspan="3">Historic skill*</th><th rowspan="2">Forecast summary</th></tr>
<tr><th>RMSE[1]</th><th>Classification error (%)[2]</th><th>MCC[3]</th></tr>
<tr><td>Good or better (< 1 mm³/l)</td><td>Low (36%)</td><td rowspan="2">1.46</td><td rowspan="2">0.95</td><td rowspan="2">13</td><td rowspan="2">0.78</td><td rowspan="2">Cyanobacteria is expected to be Moderate or worse.
Confidence level: Medium</td></tr>
<tr><td>Moderate or worse (≥ 1 mm³/l)</td><td>Medium (64%)</td></tr>
</table>

*Click here for a plot summarising historic skill

Colour (growing season mean)

<table>
<tr><th rowspan="2">Class</th><th rowspan="2">Probability of class</th><th rowspan="2">Forecasted value (mg Pt/l)</th><th colspan="3">Historic skill*</th><th rowspan="2">Forecast summary</th></tr>
<tr><th>RMSE[1]</th><th>Classification error (%)[2]</th><th>MCC[3]</th></tr>
<tr><td>Low (< 48 mg Pt/l)</td><td>Medium (74%)</td><td rowspan="2">41.8</td><td rowspan="2">9.4</td><td rowspan="2">23</td><td rowspan="2">0.47</td><td rowspan="2">Colour is expected to be Low.
Confidence level: Low</td></tr>
<tr><td>High (≥ 48 mg Pt/l)</td><td>Low (26%)</td></tr>
</table>

*Click here for a plot summarising historic skill
[1]Root mean square error: the likely error between forecasted and observed values. Units are the same as the forecasted value.
[2]Classification error: percent of time the model predicted the class incorrectly during the historic assessment period.
[3]MCC: Matthew's correlation coefficient. A value of 1 is a perfect fit to historic observations, 0 no better than a random model.

Disclaimer: Although models have generally good historic skill, if climatic and/or management conditions change relative to the historic period, forecasts may be highly inaccurate even when the confidence level is reported as 'High'. Data used to assess historic skill are from the main body of Vanemfjorden and do not necessarily reflect conditions at the more popular bathing beaches. Historically, toxic algal blooms occurred more frequently at these bathing spots and are therefore likely to be underpredicted by the forecast.

Seasonal forecast of climate and lake water quality

Forecast for Lake Vansjø for (early) summer 2004. Forecast issued 10th April 2004

This page shows temperature and precipitation conditions expected for south-eastern Norway during the next three months. For summer (May-Oct), lake water quality forecasts for the western basin of Lake Vansjø (Vanemfjorden) are also produced, to predict ecological status according to the Water Framework Directive.

Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
April	Summer water quality Early summer climate	May - October May - July
July	Late summer climate	August - October
October	Early winter climate	November - January
January	Late winter climate	February - April

Forecasts are issued by NIVA as part of the ERA4CS-funded WATExR project

Climate forecast for May 2004 – July 2004

A guide to interpreting seasonal climate forecasts accompanies this bulletin.

Temperature

Tercile	Probability	Historic skill*	Forecast summary
Cooler than normal	Medium (64%)	None	Forecast confidence is **too low** to make temperature predictions for the coming season
Normal	Very low (32%)	None	
Warmer than normal	Very low (4%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Precipitation

Tercile	Probability	Historic skill*	Forecast summary
Drier than normal	Low (48%)	None	Forecast confidence is **too low** to make precipitation predictions for the coming season
Normal	Very low (28%)	None	
Wetter than normal	Very low (24%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Confidence score guide used to generate forecast summary*

Probability of the tercile	Historic skill	Confidence that tercile will happen	Confidence that tercile won't happen
Very low (less than 35%)	Some (significant ROCSS)	Very low	High
Low (35% - 50%)		Low	Medium
Medium (50% - 65%)		Medium	Low
High (65% or more)		High	Very low
Any value	None (insignificant ROCSS)	None	None

*See accompanying guide "Understanding and interpreting seasonal climate forecasts" for more details

Lake chemistry and ecology forecast for May 2004 – October 2004

Lake water quality forecasts are for the western basin of Lake Vansjø (Vanemfjorden) and aim to predict ecological status according to the Water Framework Directive (WFD). A guide to interpreting these forecasts accompanies this bulletin.

Total phosphorus (growing season mean)

WFD class	Probability of class	Forecasted value (µg/l)	Historic skill*			Forecast summary
			RMSE[1]	Classification error (%)[2]	MCC[3]	
Upper Moderate or better (< 29.5 µg/l)	Low (32%)	31.1	3.9	33	0.34	TP is expected to be lower Moderate or worse. Confidence level: Very low
Lower Moderate or worse (≥ 29.5 µg/l)	Medium (68%)					

*Click here for a plot summarising historic skill

Chlorophyll-a (growing season mean)

WFD class	Forecasted value (µg/l)	Predicted class[a]	Historic skill*			Forecast summary
			RMSE[1]	Classification error (%)[2]	MCC[3]	
Moderate or better (< 20 µg/l)	16.8	Moderate or better	4.6	11	0.71	chl-a is expected to be Moderate or better. Confidence level: Medium
Poor or worse (≥ 20 µg/l)						

[a]A simpler forecasting model was used for chl-a (see accompanying guide), so no class probabilities are available.
*Click here for a plot summarising historic skill

Cyanobacteria (growing season maximum)

WFD class	Probability of class	Forecasted value (mm^3/l)	Historic skill*			Forecast summary
			RMSE[1]	Classification error (%)[2]	MCC[3]	
Good or better (< 1 mm^3/l)	Low (49%)	1.04	0.95	13	0.78	Cyanobacteria is expected to be Moderate or worse. Confidence level: Medium
Moderate or worse (≥ 1 mm^3/l)	Medium (51%)					

*Click here for a plot summarising historic skill

Colour (growing season mean)

Class	Probability of class	Forecasted value (mg Pt/l)	Historic skill*			Forecast summary
			RMSE[1]	Classification error (%)[2]	MCC[3]	
Low (< 48 mg Pt/l)	Medium (73%)	42.1	9.4	23	0.47	Colour is expected to be Low. Confidence level: Low
High (≥ 48 mg Pt/l)	Low (27%)					

*Click here for a plot summarising historic skill
[1]Root mean square error: the likely error between forecasted and observed values. Units are the same as the forecasted value.
[2]Classification error: percent of time the model predicted the class incorrectly during the historic assessment period.
[3]MCC: Matthew's correlation coefficient. A value of 1 is a perfect fit to historic observations, 0 no better than a random model.

Disclaimer: Although models have generally good historic skill, if climatic and/or management conditions change relative to the historic period, forecasts may be highly inaccurate even when the confidence level is reported as 'High'. Data used to assess historic skill are from the main body of Vanemfjorden and do not necessarily reflect conditions at the more popular bathing beaches. Historically, toxic algal blooms occurred more frequently at these bathing spots and are therefore likely to be underpredicted by the forecast.

Australia's Forecasts

Seasonal forecast of climate and reservoir temperature and discharge

Forecast for Mt Bold for summer 2006. Forecast issued 10th November2006

This page shows temperature and precipitation conditions expected for South Australia during the next three months. For summer (Dec-Feb), lake temperature and catchment inflow forecasts for Mt Bold Reservoir are also produced, to predict surface and bottom temperatures and discharge.

Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
May	Spring climate, water temperature and water level	June – August
August	Winter climate, water temperature and water level	September - November
November	Summer climate, water temperature and water level	December – February
February	Autumn climate, water temperature and water level	March – May

Forecasts are issued by DkIT as part of the ERA4CS-funded WATExR project

Climate forecast for December 2005 – February 2006

Temperature

Tercile	Probability	Historic skill*	Forecast summary
Cooler than normal	Very low (16%)	None	Forecast confidence is **too low** to make temperature predictions for the coming season
Normal	Very low (32%)	None	
Warmer than normal	Medium (52%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Precipitation

Tercile	Probability	Historic skill*	Forecast summary
Drier than normal	Low (40%)	None	Forecast confidence is **too low** to make precipitation predictions for the coming season
Normal	Very low (36%)	None	
Wetter than normal	Very low (24%)	None	

*Click here for tercile plots summarising historic skill and ROCSS values

Confidence score guide used to generate forecast summary*

Probability of the tercile	Historic skill	Confidence that tercile will happen	Confidence that tercile won't happen
Very low (less than 35%)	Some (significant ROCSS)	Very low	High
Low (35% - 50%)		Low	Medium
Medium (50% - 65%)		Medium	Low
High (65% or more)		High	Very low
Any value	None (insignificant ROCSS)	None	None

*See accompanying guide “Understanding and interpreting seasonal climate forecasts” for more details

Discharge and lake temperature forecast for December 2005 – February 2006

A guide to interpreting these forecasts accompanies this bulletin.

Discharge – Onkaparinga

Tercile	Probability of class	Historic skill* ROCSS	Forecast summary
Lower than normal	32%	0.18	Discharge is highly unpredictable with a possi-bility of all scenarios Confidence level: Very low
Normal	32%	0.03	
Higher than normal	36%	-0.20	

Discharge – Echunga

Tercile	Probability of class	Historic skill* ROCSS	Forecast summary
Lower than normal	8%	0.16	Discharge is expected to be normal Confidence level: Very low
Normal	64%	-0.02	
Higher than normal	28%	-0.22	

Surface temperature – Mt Bold

Tercile	Probability of class	Historic skill* ROCSS	Forecast summary
Lower than normal	12%	0.13	Surface temperature is expected to be normal or higher than normal Confidence level: Very low
Normal	40%	-0.14	
Higher than normal	48%	-0.10	

Bottom temperature – Mt Bold

Tercile	Probability of class	Historic skill* ROCSS	Forecast summary
Lower than normal	0%	0.63*	Bottom temperature is expected to be higher than normal Confidence level: Very low
Normal	4%	-0.10	
Higher than normal	96%	0.29	

Water level– Mt Bold

Tercile	Probability of class	Historic skill* ROCSS	Forecast summary
Lower than normal	0%	0.20	Water level is expected to be normal Confidence level: Very low
Normal	68%	0.12	
Higher than normal	32%	0.03	

Disclaimer: Although models have generally good historic skill, if climatic and/or management conditions change relative to the historic period, forecasts may be highly inaccurate even when the confidence level is reported as 'High'.

Spain's Forecasts

Seasonal forecasting for Sau Reservoir and Ter River
Autumn 2019

Prediction

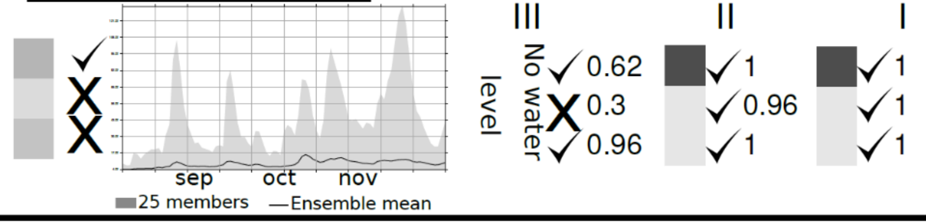
Streamflow (Q)

Streamflow has skillful prediction in the above tercile

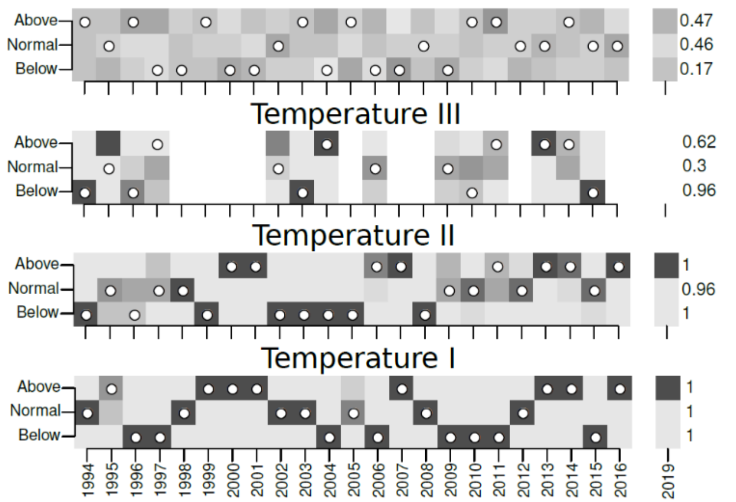
Temperature (T)

Gate III has skillful prediction in above and below terciles
Gate II has skillful prediction in above, normal and below terciles
Gate I has skillful prediction in above, normal and below terciles

Prediction



Historical analysis



Databases used

Seasonal forecasting system:
SEAS5
Hindcast 1994-2016

Reanalisis/pseudoobservation:
ERA5
1988-2020

How to use?

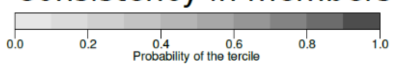
This is a first attend to report a seasonal forecasting prediction for streamflow for Ter River and temperature for Sau Reservoir. It should never be taken as a deterministic results, but probabilistic, according to the nature of the meteorological data used. The tercile plots presented here should be analise according to the information section of this report. More information can be obtained from developers rmarce@icra.cat and dmercado@icra.cat

Funded by:

X Non-significant tercile
✓ Significant tercile

Terciles
above
normal
below

Consistency in members



Level of the gates
Gate III (-11.04m)
Gate II (-25.54m)
Gate I (-40.04m)

Germany's Forecasts

Seasonal forecast of climate and reservoir temperature

Forecast for Wupper reservoir for summer 2003. Forecast issued 10th November2006

This page shows temperature and precipitation conditions expected for western Germany during the next three months. For summer (Jun-Aug), lake temperature and catchment inflow forecasts for Wupper Reservoir are also produced, to predict surface and bottom temperatures and discharge.

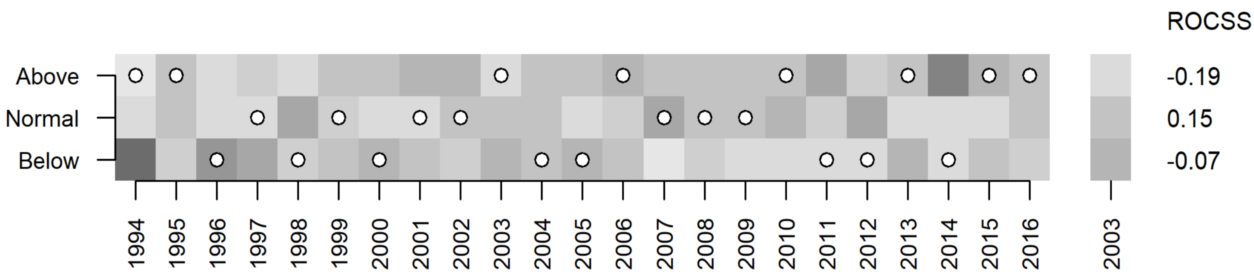
Forecasts are issued four times a year, as follows:

Issued	Forecast season and variable	Months in forecast
April	Summer climate	May - October May - July
July	Late summer climate	August - October
October	Early winter climate	November - January
January	Late winter climate	February - April

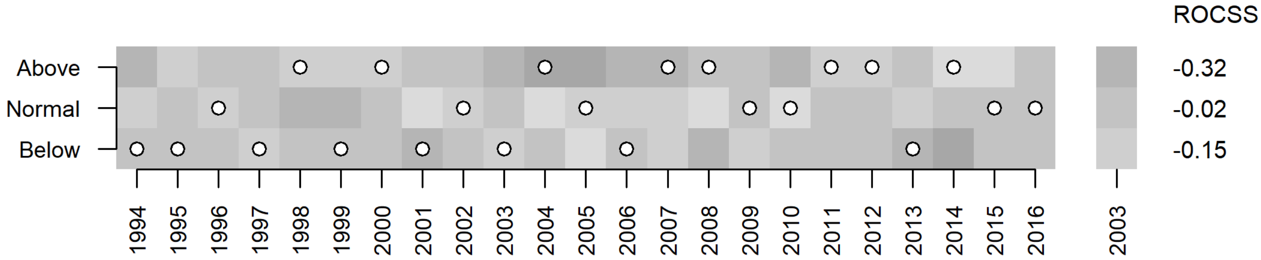
Forecasts are issued as part of the ERA4CS-funded WATExR project

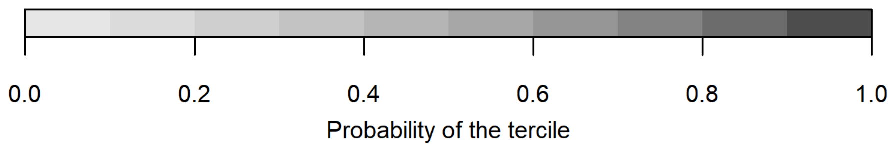
Climate forecast for June 2003 – August 2003

Temperature



Precipitation

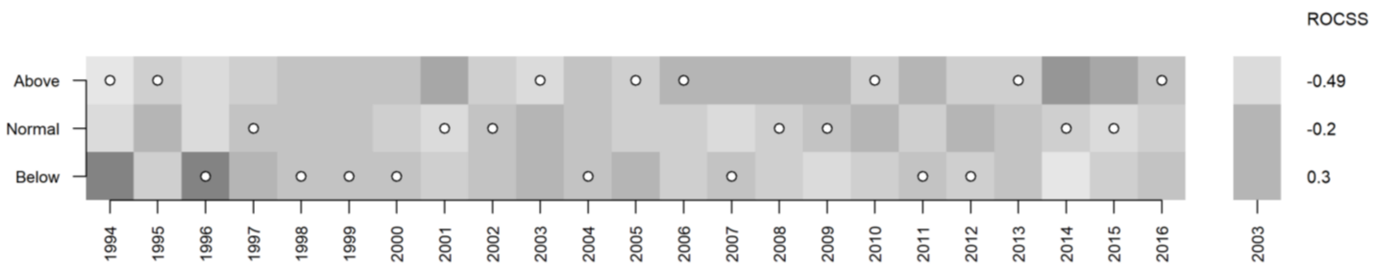




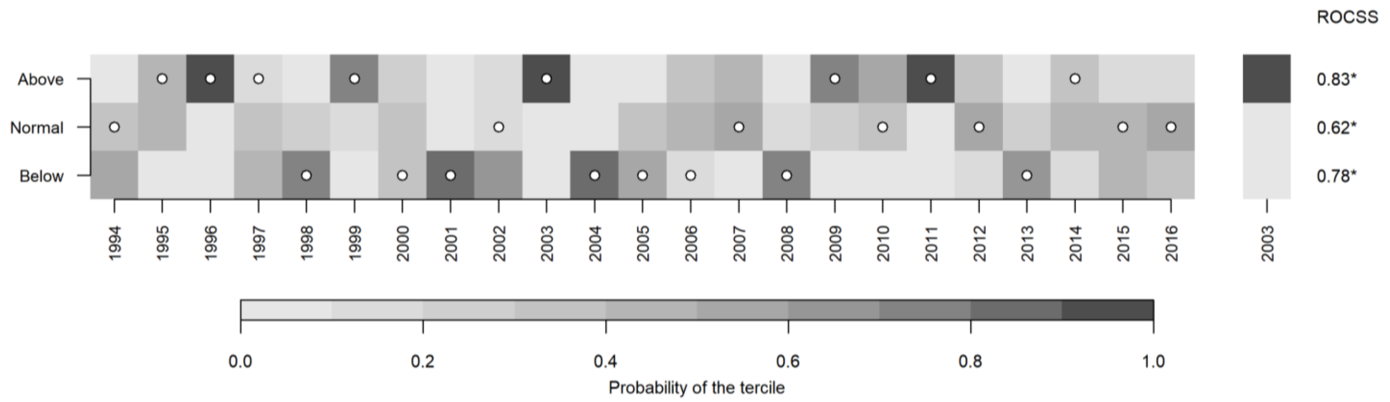
The forecast of the climate data showed very low skills for the event chosen by the stakeholder, for example the air temperature and precipitation.

Lake temperature forecast for June 2003 – August 2003

Surface temperature



Bottom temperature



But the lake model had a very high skill in predicting bottom temperatures. For bottom temperature, forecasts predicted the upper tercile which corresponds to the observations consistent with the 2003 heatwave.