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Climate Futures for Reisa National Park

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Executive Summary

This report presents the results of a co-developed climate impact assessment for Reisa National Park, carried out in close collaboration with park managers to ensure practical relevance and scientific rigor. The assessment focused on five key management priorities spanning ecosystems and visitor access, and used high-resolution climate projections to evaluate how these priorities may be affected under a range of future climate scenarios.

Key findings include:

- **Spring flooding** emerges as the most significant risk, with projections indicating a potential doubling of river flow in the coming decades.
- **Winter access** along frozen rivers is expected to decline sharply due to warmer and shorter winters.
- **Summer river access** and **Atlantic salmon habitats** are increasingly threatened by reduced runoff, despite rising precipitation.
- **Vegetation and growing conditions** are projected to change substantially, with large increases in growing degree days.
- **Wildfire risk**, in contrast, is not projected to increase significantly—even under high-emissions scenarios—due to increased summer rainfall and fewer dry days.

The full set of interactive visualizations and climate metrics can be explored at:
https://seasonalforecastsfornorway.shinyapps.io/Reisa_app/

Approach

This project set out to understand how climate change might affect key aspects of Reisa National Park in the coming decades. To do this, we worked closely with park managers to identify which areas are most important to protect and manage. These included natural ecosystems and the services they provide—such as habitats for wildlife, forest health, and access for visitors.
Together, we focused on five main priorities, grouped into three themes:

Vegetation	Wildlife	Outdoor activities		
Pine forest (Wildfires)	Atlantic Salmon (Heat stress)	Main trail (snow melt and flooding)	Summer river transport (Low water level)	Winter river transport (Ice stability)

We held two online workshops with park managers where we identified the key climate drivers of each of these priorities —things like temperature extremes, snowfall, and rainfall patterns. Each participant gave their input, and we reached agreement on around five key climate metrics (or "drivers") for each priority. These are the basis for the climate analysis in the Results section.

This agreement was achieved by first creating an Excel sheet that listed all the climate metrics in the rows and the priorities in the columns. All participants then indicated the metrics they thought were important for each driver by putting a cross in the corresponding cell. The cells which had the most crosses, where the greatest number of people agreed that that climate metric was important for that priority, were then taken as the climate metrics to take forward for further analysis. For example, everyone agreed that the number of hot summer days was an important metric for Atlantic Salmon, so this was included. The Excel sheet that we created as part of this process is included in Annex 1. This also includes a definition of all climate metrics used in this report.

We looked at how climate change could affect Reisa National Park by creating three different future scenarios, or “climate futures.” These cover three time periods:

- Near future: 2026–2050
- Mid-century: 2051–2075
- Far future: 2076–2100

By dividing the future into these windows, we can give park managers a clearer picture of what changes are most likely to happen—and when—so they can plan accordingly.

To do this, we used a large set of climate projections from the CORDEX project, which combines global and regional climate models. These models simulate how the climate might change during the 21st century under different levels of greenhouse gas emissions. The CORDEX dataset includes over 70 different climate simulations for Europe, all at a resolution of about 11 km.

Our first step was to collect temperature and rainfall data from all 70 models. Each simulation gives a different but equally possible future. In Figure 1, each dot represents one model's estimate of how temperature and rainfall might change in the region by the end of the century.

As expected, we found a strong link between how much the climate warms and how much more precipitation is expected. This makes sense—warmer air holds more moisture, so more rain or snow can fall. However, there’s also a lot of uncertainty in how much warming and precipitation change we should expect. For example, some models show just 2°C of warming with no change in rainfall, while others show up to 7°C of warming with 40% more precipitation. Part of this spread comes from uncertainty about future global emissions, and part comes from how the climate system itself responds.

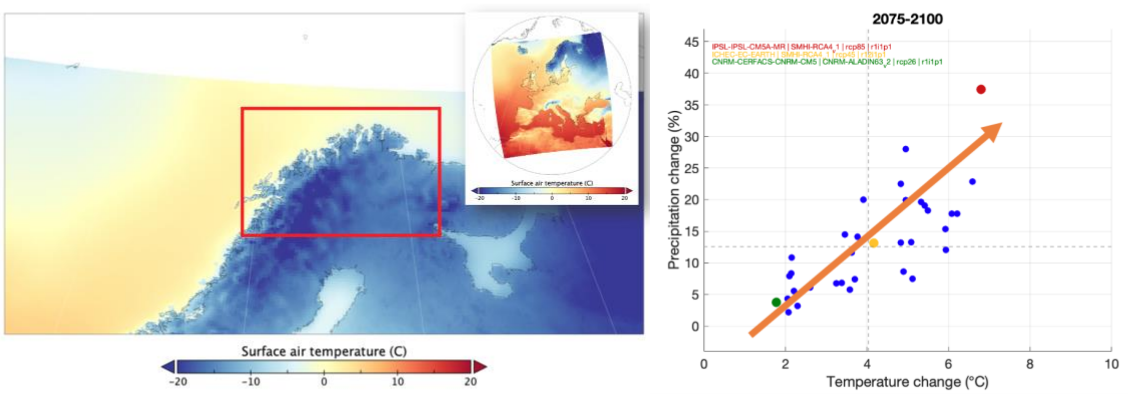

Figure 1. The figure on the left shows the region we defined to assess the overall picture of regional climate change, indicated by the red box. The figure on the right shows the annual-average change in Temperature (^{o}C anomaly from the historical baseline of 1970-1990) and Precipitation (% change from historical baseline in 1970-1990) for the climate in the window 2075-2100.

Because there is such a wide range of possible climate outcomes, we selected three specific models from the CORDEX set to represent that full range. These were:

- One with the **least amount of warming** (shown as a green dot in Figure 1),
- One with a **moderate, middle-of-the-road level of warming** (yellow dot),
- And one with the **most extreme warming and precipitation increases** (red dot).

These three models allow us to explore the full range of what the future might look like—from the mildest to the most severe outcomes. The yellow model (ICHEC) represents our best estimate of the most likely future, while the other two help us understand the limits of what could happen.

For each of these three models, we calculated a set of climate metrics—things like the number of hot summer days, length of the winter season, and amount of rainfall—that had been agreed upon during our workshops with park managers. These are the key climate factors that affect Reisa’s ecosystems and visitor access.

To make these projections useful at the local scale of the park, we used a tool called KrigR, developed by the Nansen Center. This tool allows us to "zoom in" on the data—from the original 11 km resolution down to about 300 meters. It does this by using known relationships between variables like temperature and elevation. For example, it might use the fact that higher areas tend to be cooler to improve the detail of our results.

This means we can show much finer detail across the park. For instance, Figure 2 shows how the valley floor is expected to warm much more than the higher mountain slopes around it.

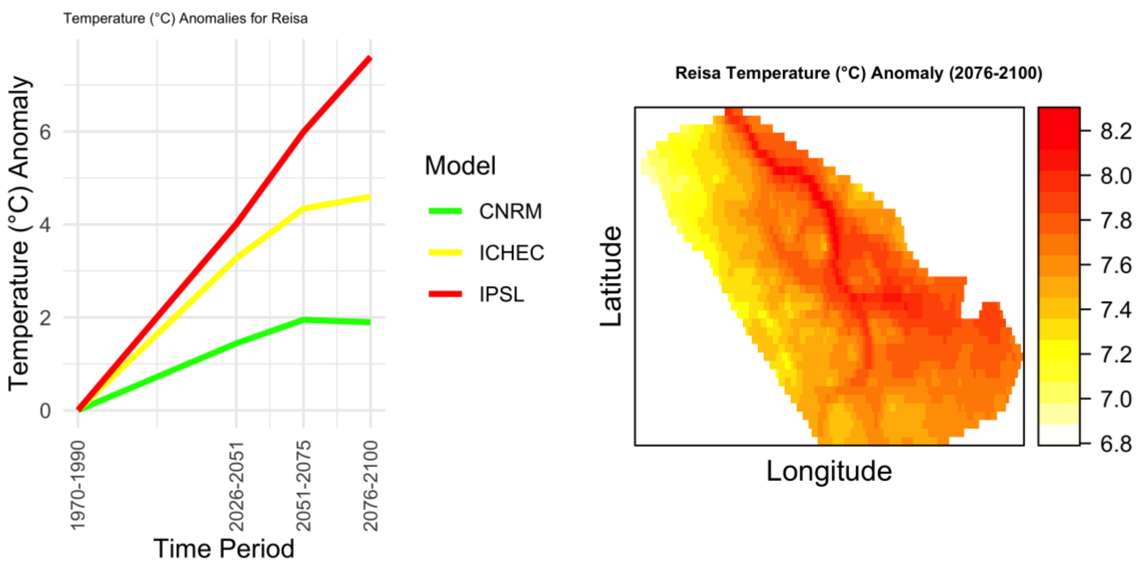

Figure 2. The figure on the left shows the temperature anomaly for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of temperature anomalies for the high emission scenario for the period 2076-2100.

Overview of climate change for Reisa

In this section, we give an overview of how the climate in Reisa National Park is expected to change over the 21st century. We looked at changes in both the annual average (what a typical year might look like) and the seasonal patterns—how winter, spring, summer, and autumn could shift over time.

When we refer to seasons, we use the standard meteorological definitions based on three-month blocks:

- **Winter**: December, January, February
- **Spring**: March, April, May
- **Summer**: June, July, August
- **Autumn**: September, October, November

To keep things simple and focused, this report includes a selection of the most important figures that highlight key findings. However, if you're interested in digging deeper, you can find visual summaries for all climate metrics in Annex 2.

Warming and changing seasonality

Figure 2 shows how average yearly temperatures in Reisa are expected to rise over time—but when we break it down by season, we see some important differences in how quickly and how much the climate warms.

Winter is projected to warm the most. In the worst-case, high-emissions scenario, winter temperatures could rise by up to 11°C by the end of the century (Figure 3). That's a dramatic shift. On the other hand, in the lowest emissions scenario, winter warming is limited to just 2°C—which is relatively mild, and about the same as the expected global average in that scenario.

Summer temperatures are expected to increase more slowly. In the middle emissions scenario, summer warms by about 3°C, which is only half as much as winter does in the same scenario. But under the high-emissions scenario, summer warming speeds up sharply in the second half of the century, reaching up to 6°C by 2100.

This kind of pattern—where the change between the middle and high scenarios is much larger than between the low and middle—is called a non-linear response. These jumps can be important to watch out for, because they suggest that risks could increase suddenly if emissions are not kept in check.

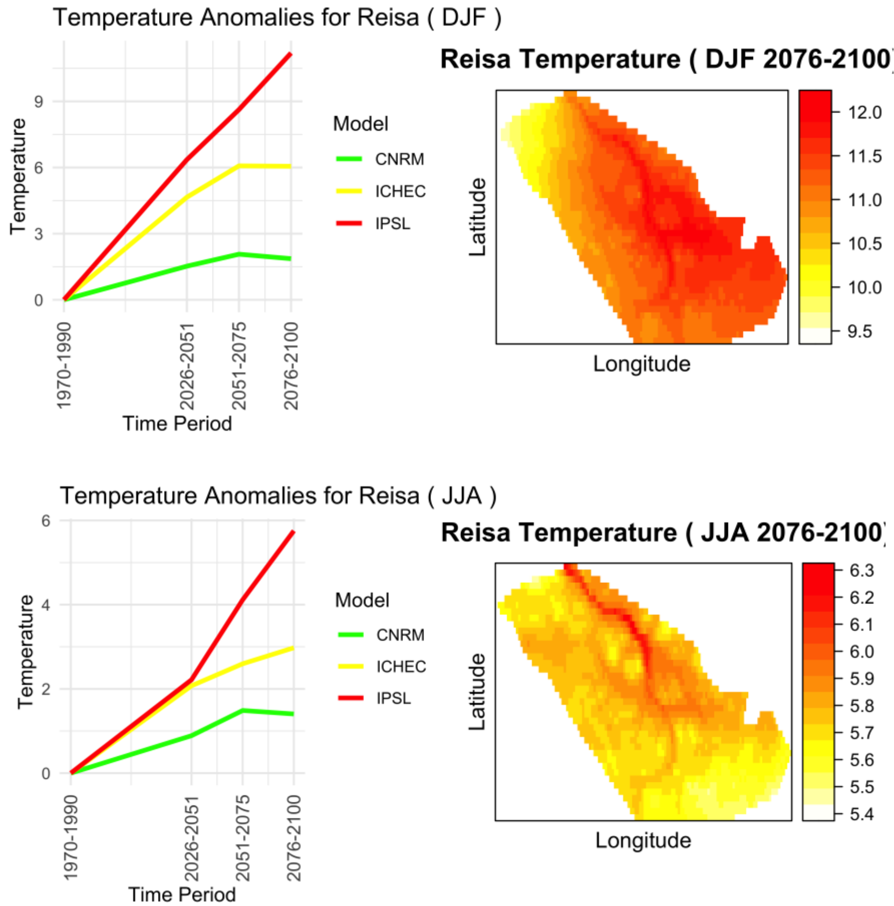

Figure 3. The figures on the left shows the temperature anomaly for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figures on the right shows the map of winter temperature anomalies for the high emission scenario for the period 2076-2100. These are shown for Winter (upper) and Summer (lower).

The length of the winter season in Reisa is expected to shrink significantly as the climate warms (Figure 4). Winter here is defined as the time of year when temperatures stay below freezing, and even in the lowest emissions scenario, winter is expected to get 20 days shorter within the next 25 years. Under high emissions, the reduction is much more dramatic—up to 80 fewer winter days by the end of the century. And the trend would likely continue into the 22nd century.

At the same time, summer will get longer, but not by as much. Summer is defined as the period when temperatures stay above freezing. For instance, under a mid-level emissions scenario, winter could become 50 days shorter, while summer only extends by 20 days. What fills in the gap is a much longer spring season, when temperatures hover around 0°C—often swinging back and forth across the freezing point.

This shift toward longer, milder, and more unstable springs is especially important, because it creates riskier conditions for many park priorities—like flooding, ice instability, and habitat changes. Spring is also expected to start 1–2 weeks earlier than it did during the reference period of 1970–1990.

As summers lengthen and the overall climate warms, we'll also see more hot days—defined as days when temperatures go above 20°C (see Annex 2). This is especially noticeable along the valley floor, where temperatures are generally higher than on the surrounding mountains. Even in the low emissions scenario, we can expect about a week of such hot days each summer along the Reisa river.

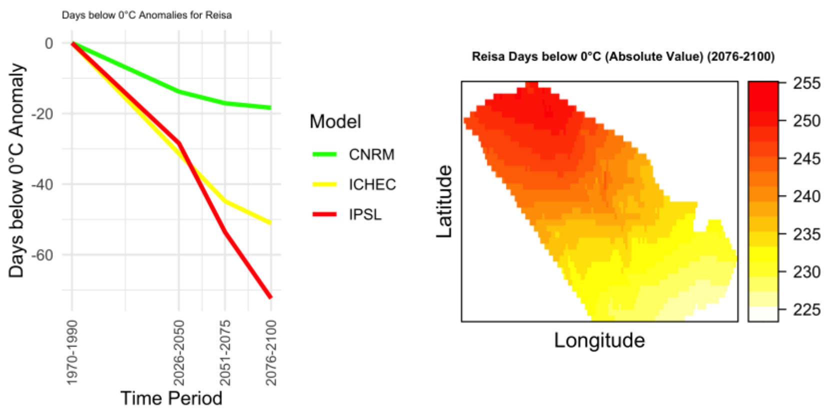

Figure 4. The figure on the left shows the change in the length of winter for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of the length of winter in days for the high emission scenario for the period 2076-2100.

As the climate gets warmer and summers become longer, there will be a big increase in the amount of energy available for plant growth. This is measured using something called "growing degree days," which is the total number of degrees above freezing that occur over the course of a year. The more growing degree days there are, the more potential there is for plants and vegetation to grow.

Even in the lowest emissions scenario, growing degree days are expected to increase by about 40 percent. In the high emissions scenario, this increase could be as much as 500 percent by the end of the century (Figure 5). However, this change doesn't happen evenly across the park. The south-eastern part of Reisa is projected to get almost twice as many growing degree days as the north-western part. Elevation also plays a big role, so the valley floor—being lower and warmer—is expected to see some of the biggest increases in growing potential throughout the park.

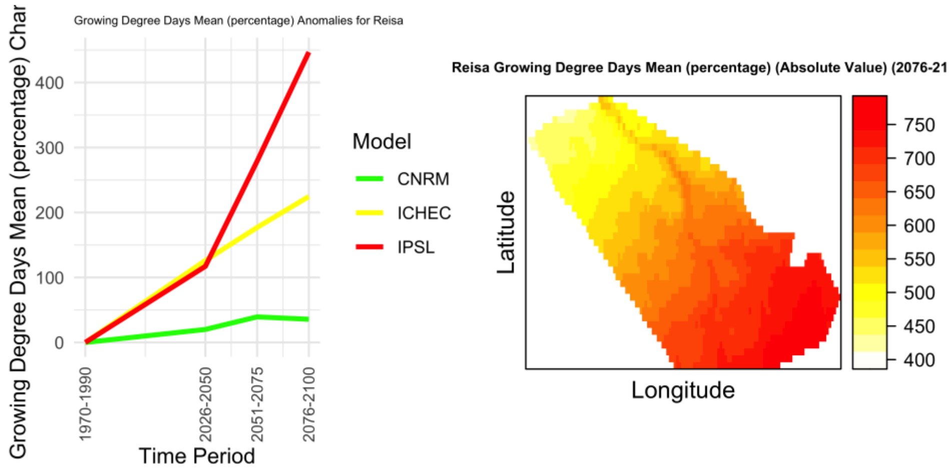

Figure 5. The figure on the left shows the change in the growing degree days for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of the Growing degree days for the high emission scenario for the period 2076-2100.

Changes to Snow cover

Although the average snow depth across the year is only expected to decrease by up to 20 percent, the way snow falls and how long it stays on the ground will change quite a lot—even under a mid-level emissions scenario.

As summers get longer and warmer, snowfall is expected to start later in the year. This means the biggest drop in snow depth will happen in the autumn months, with up to a 50 percent reduction in snow cover by that time of year, even under a moderate emissions pathway (Figure 6).

A warmer climate will also bring a big increase in what are called "rain-on-snow events." These happen when at least 1 mm of rain falls on top of at least 5 cm of snow. Right now, this only occurs for about one week each year, on average. But in a mid-emissions scenario, this could nearly triple—adding almost two more weeks of rain-on-snow events.

Most of this increase is expected to happen in the spring, when temperatures are close to freezing. But even winter months may start to see more of these events as the climate continues to warm.

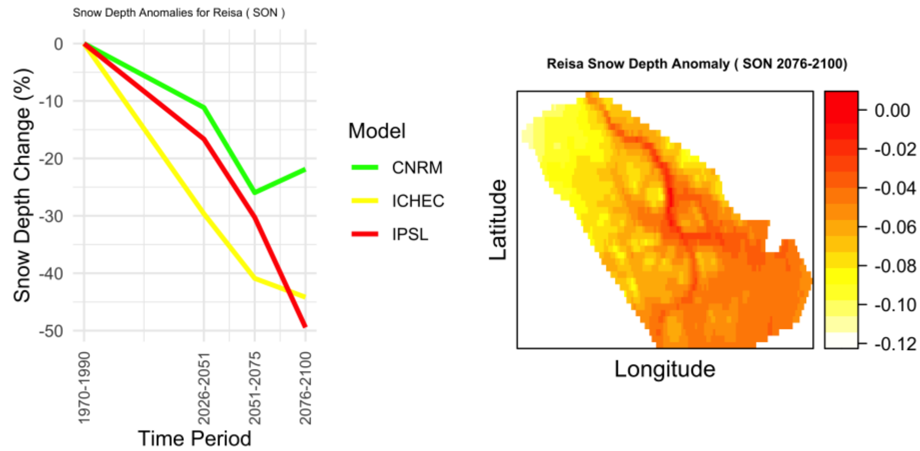

Figure 6. The figure on the left shows the percentage change in the snow depth for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of the Snow depth anomalies for the high emission scenario for the period 2076-2100.

Changes to precipitation

There is a lot of uncertainty when it comes to how rainfall will change in the future. This is because the amount of water the atmosphere can hold increases in a non-linear way with temperature. In simple terms, a 2°C rise in temperature leads to more than twice the increase in rainfall you'd get from a 1°C rise.

This non-linear effect is one of the reasons why rainfall projections vary so much. For example, looking at average yearly rainfall changes by the end of the century, we see an increase of about 5 percent in the low emissions scenario, 25 percent in the mid emissions scenario, and 50 percent in the high emissions scenario (Figure 7).

We see a clear North-west to South-East gradient in the changes to precipitation, as well as an elevation dependence – so there is less increase in precipitation along the valley floor than there is on the surrounding mountaintops. A similar pattern to Figure 7 is found in all seasons, although in Autumn we see both the low and the mid emissions scenarios have a similar increase in precipitation in the 21st century of around 15%.

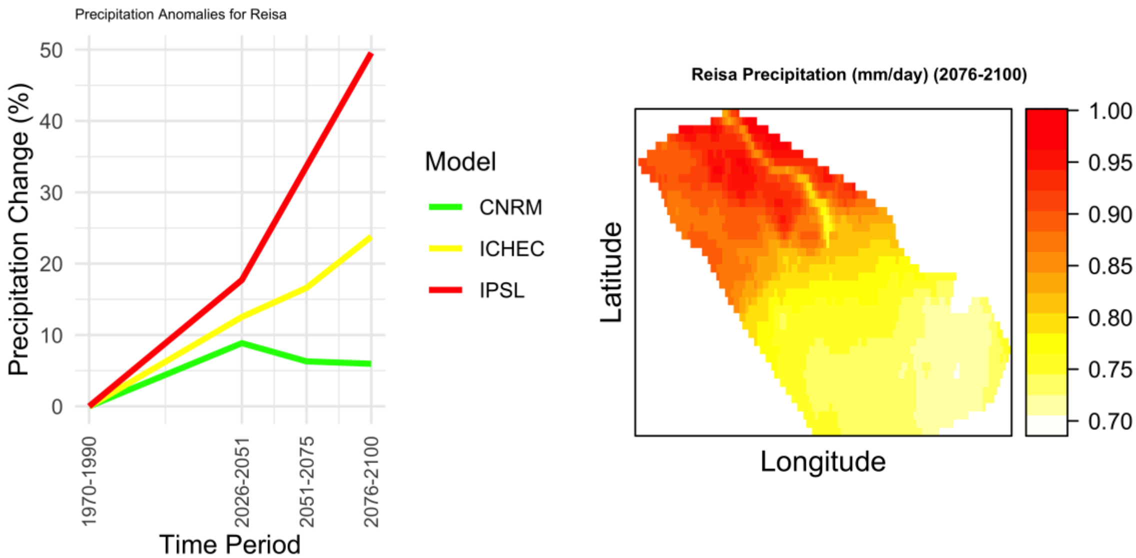

Figure 7. The figure on the left shows the percentage change in precipitation for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of the precipitation change in mm/day for the high emission scenario for the period 2076-2100.

As overall rainfall increases, we also expect more days with heavy rain (more than 10 mm in a day) and extreme rain (more than 30 mm in a day). Depending on the emissions scenario, the number of heavy rainfall days is expected to rise by 2 to 8 days per year. For extreme rainfall, the increase is more modest—about 1 to 2 extra days per year, regardless of scenario. These heavier rain events are most likely to happen during summer and autumn.

Rainfall will also become more frequent in general. This means there will be fewer dry spells, with the number of consecutive dry days falling by 1 to 3 days, depending on the scenario. The biggest reductions are seen in the mid and high emissions futures. At the same time, there will be a small increase in the number of consecutive wet days—usually 1 to 2 more days each year.

These changes in rainfall don't just affect how wet it is—they also influence how much runoff ends up in rivers and streams. Runoff depends not just on how much rain falls, but also how often, how intensely, and how persistently it falls. All of this is captured in the runoff projections.

Runoff is expected to change very differently from one season to another. In spring, there will be a large increase in runoff—ranging from 25 to 150 percent, depending on the emissions scenario. In the mid-emissions case, runoff could double by mid-century (Figure 8). This is due to a combination of more rainfall and more intense rain events during spring.

There is a very large gradient in the increase in runoff across the park from North-West to South-East. In summer, however, runoff is expected to decrease in all scenarios. The reduction ranges from about 15 to 40 percent, depending on the level of emissions. This drop in summer runoff will likely lead to lower river flows, especially during the peak visitor season.

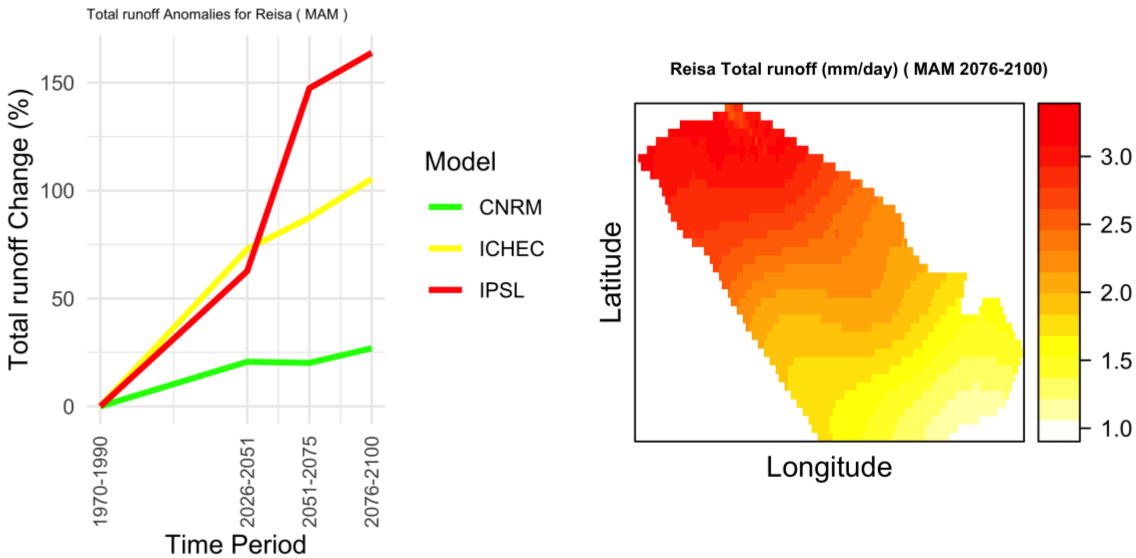

Figure 8. The figure on the left shows the percentage change in runoff for the park for each of the future periods under each of the low (green), mid (yellow), and high (red) emissions scenarios. The figure on the right shows the map of the runoff change in mm/day for the high emission scenario for the period 2076-2100.

Online tool for exploring climate futures by priority

To give an overview of how all these changes to the climate can affect the different priorities we identified for Reisa national park, I have created a web-tool to help visualize these. It is available at https://seasonalforecastsfornorway.shinyapps.io/Reisa_app/. In this chapter I will introduce the tool and how to use it to explore climate futures for Reisa national park. A snapshot from the website is shown in Figure 9. Here at the top, you can select amongst different Future periods (2026-2050, 2051-2075, 2076-2100) and emissions scenarios (Low, Mid, High). When you select these, the map and the timeseries below will be automatically updated.

Below these options you can find a drop-down menu to select between the different priorities that we identified for Reisa in our workshops e.g. Forest fires, River Winter access. When you select a priority, the list of climate metrics will automatically be updated to only show those metrics which we agreed were most important for that priority (see Annex 1 for the full list). You can then select from the dropdown list which climate metric you want to visualize. The climate metrics are visualized in the map as the difference between the historical (1970-1990) climate and the period and emissions scenario you have selected, either as an absolute difference or as a percentage change, depending upon the metric. The change in *all* metrics associated with the selected priority are shown in the coloured boxes. These are colour-coded using a traffic-light system according to the magnitude and direction of the changes with green indicating safe, yellow indicating no change, and red indicating dangerous change. Yellow (no change) is defined as when the magnitude of change is within the range of natural variability in the historical period, 1970-1990. Safe is defined as being outside of this range of natural variability but in the direction which reduces the risk for the chosen priority, and Dangerous is defined as being outside of this range of natural variability but in the direction which increases the risk for the chosen priority. For this reason, whether a change in a metric is labelled as safe or dangerous depends upon the priority selected e.g. reduced rainfall in summer is labelled safe with respect to flooding risk, but dangerous with respect to fire risk.

You can click on the map to get the overview for that location. This will update both the coloured boxes and the timeseries displayed below the map. If you want to reset to the Park averages there is a button you can click to do so, just below the drop-down menu for the climate metrics. Next to it there is also a button for “Valley floor (main trail)”. This selects a region following the main trail where it follows the Reisa river, and it is highlighted by the black boxes on the map when you click this button.

Below the map you will find the timeseries for climate metric you have chosen to visualize. This is always shown as the absolute value, starting from the historical average from the three models (1970-1990), and following each emissions scenario. This can help a lot to understand what the changes mean. For example, the length of winter is projected to decrease by up to 65 days under high emissions, but when you look at the timeseries you can quickly see that this means that winter will be less than half as long as it used to be in this scenario (Figure 9).

Below the timeseries plot you will see a list of the different metrics associated with the chosen priority, and their definitions. It is also indicated whether the changes in this metric are calculated as a change in the value [Δ] or as a percentage change [%].

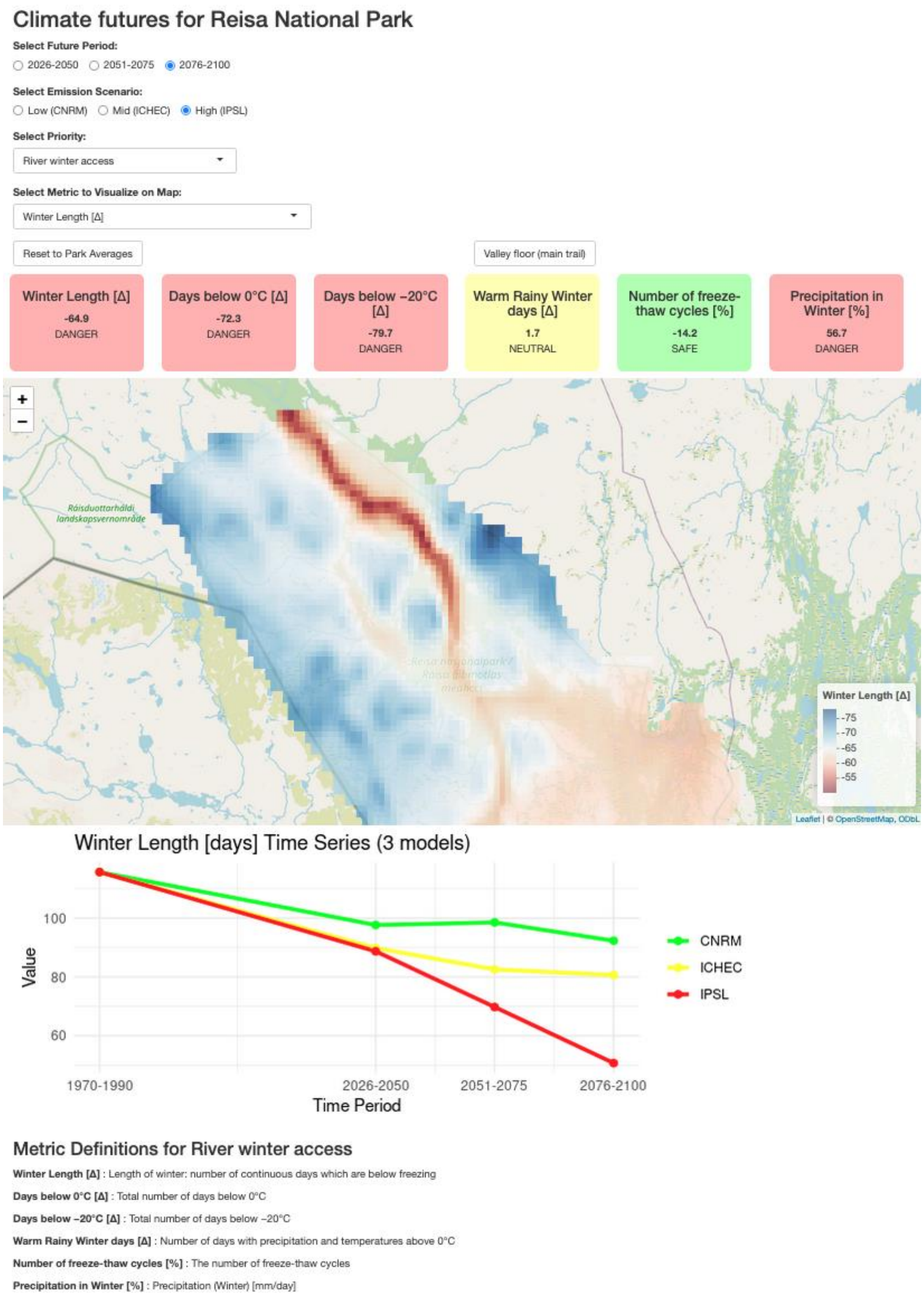

Figure 9. A snapshot from the web tool for Reisa, as described in this chapter.

Results by priority

In this chapter I will present a summary of the changes in the climate metrics associated with each priority for the mid-century (2051-2075) following a mid-emissions scenario. I will use snapshots from the web-tool to give an overview of all changes.

Forest fires

The risk of forest fires is principally linked to how dry the ground becomes, how warm it is, and how long are the periods with dry days in summer. We expect to see a moderate increase in rainfall in summer, which reduces the overall risk. This is accompanied by a reduction in the number of drought days, which also reduces the risk of creating the conditions needed for fires to spread. While there is a significant warming, ranging from 2.4 to 3.5°C across the park, this does not trigger a significant drying of the ground. So overall, there is no increase of risk of forest fires in the future compared to what has been seen in the past (Figure 10).

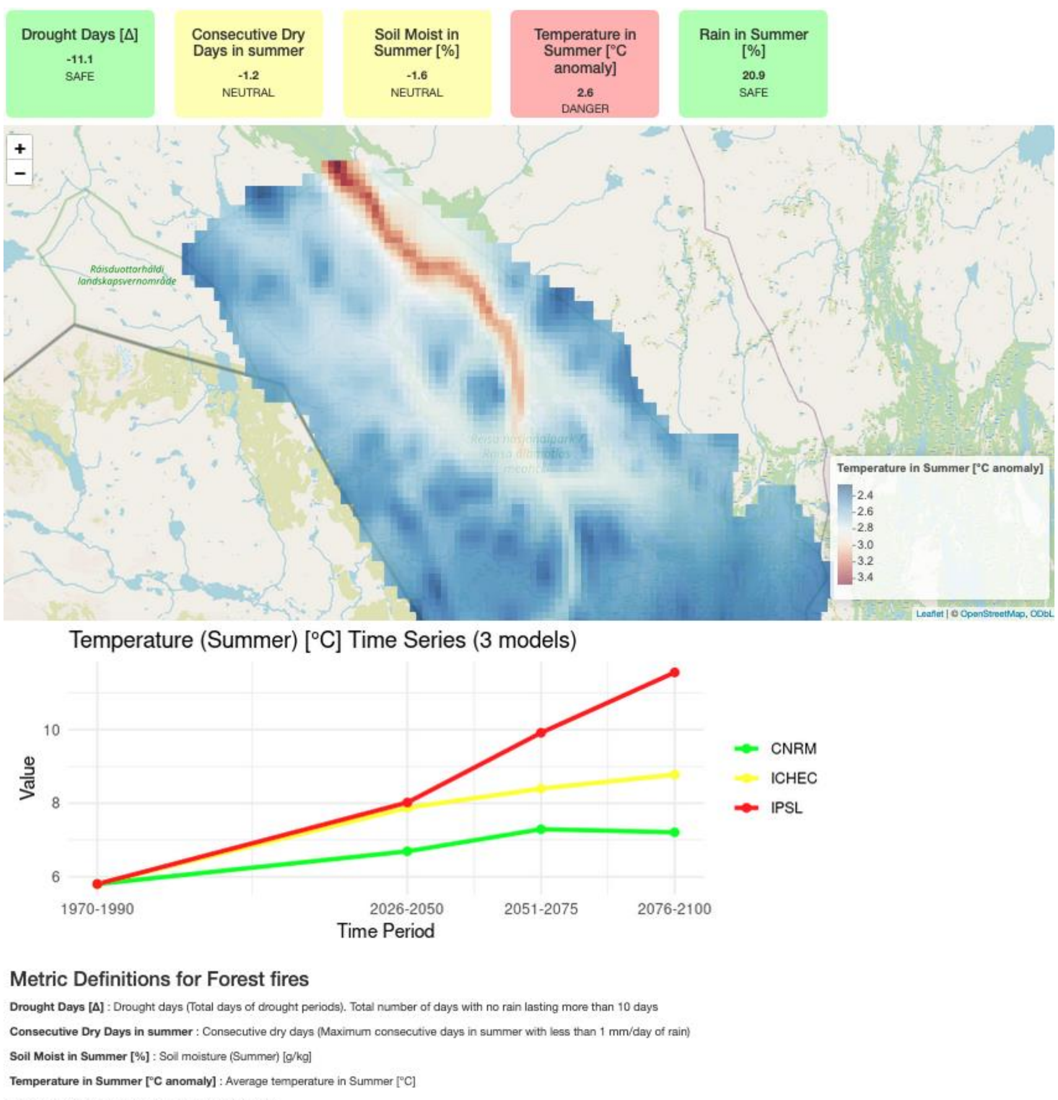

Figure 10. An overview of the risk of Forest fires in 2051-2075 under a mid-emissions scenario.

River Winter Access

Winter conditions are going to change dramatically in the near future. Winter will get shorter by about a month, and winters won't be anywhere near as cold as we are used to. The number of days below freezing is expected to be reduced by 45 days, or even more along the main trail. We can also expect just half as many days with very cold conditions (below -20°C), greatly reducing the period where the river can be expected to be stably-frozen. While there will be a moderate increase in snowfall, about 20%, we can also expect to get rainy days even in the winter months. Altogether this paints a picture of a rapidly shrinking and much milder winter season which is expected to halve the period of safe access on a frozen river by mid-century (Figure 11). This is the most severe effect of climate change in all the priorities we considered for the park.

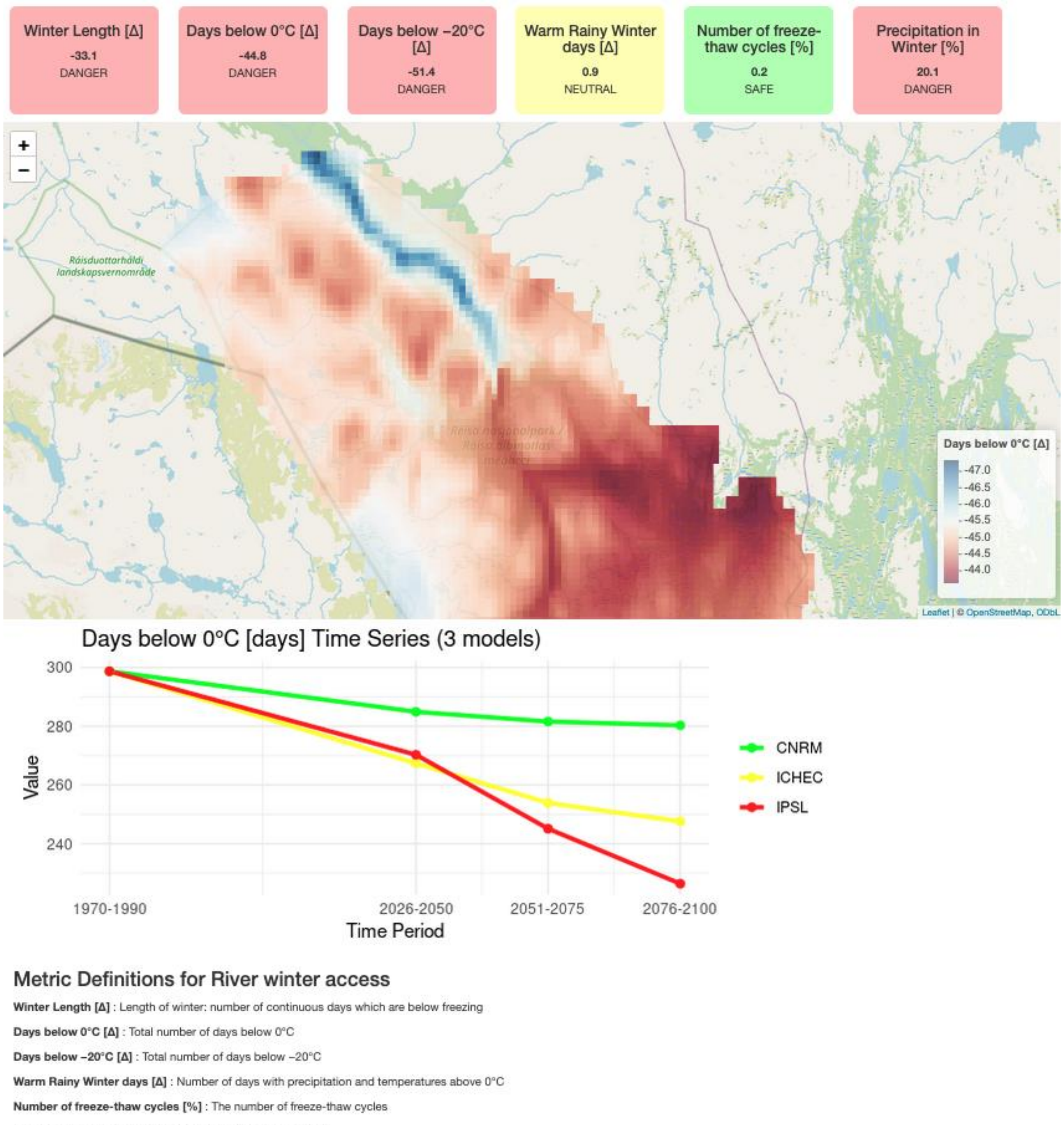

Figure 11. An overview of the risk of River Winter Access in 2051-2075 under a mid-emissions scenario.

Atlantic Salmon

Atlantic salmon are mostly sensitive to the temperature of the water in the river in summer. While we can't get information on that directly from the climate models, we can get information on the factors that affect it i.e. the amount of water in the river and the temperature of the surroundings. While there will be some warming, summer daily-high temperatures are not expected to go up that much by mid-century, and not enough to significantly increase the risk to Atlantic Salmon. Nor do we expect to see a significant change in the number of hot summer days (days with highs above 20^{o}C). But while the risk from warming land and air is not great, there is expected to be a large decrease in the runoff into the Reisa river in summer, leading to an approximately 40% drop in river flow. This can create a risk to Salmon as a shallower river will warm faster than a deeper river. Overall this leads to an increasing, but perhaps not yet severe, environmental pressure on Atlantic Salmon (Figure 12).

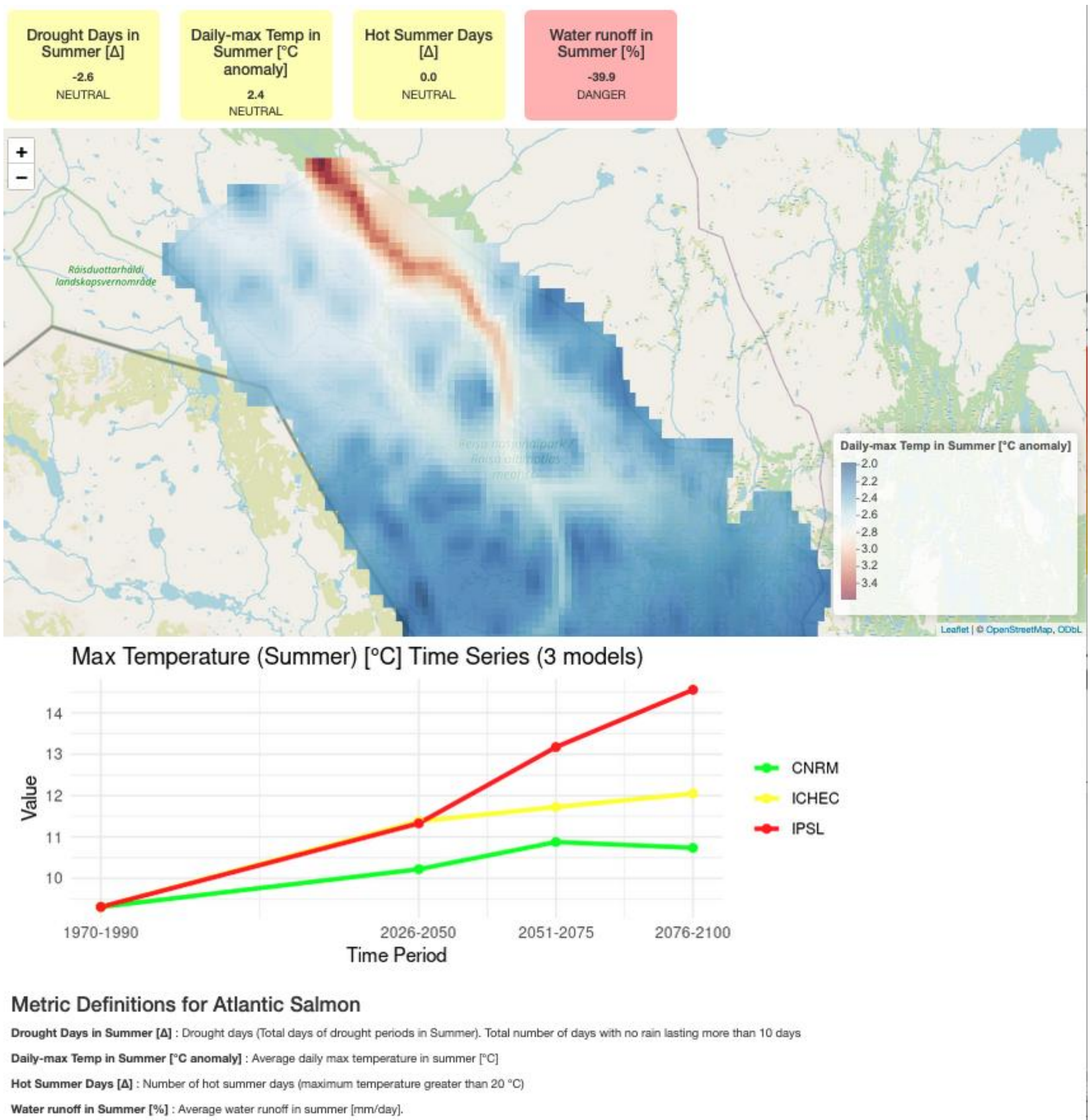

Figure 12. An overview of the risk of Atlantic Salmon in 2051-2075 under a mid-emissions scenario.

Flooding on the main trail (Spring)

The risk of flooding along the main trail in Spring is exacerbated by two main factors: more intense rainfall and an earlier start to the melt season leading to increased rain-on-snow events. These combine to make for rapidly increasing runoff into the river and therefore rising river levels. By mid-century we can expect a doubling of rain-on-snow events in spring. We also see a near-doubling of runoff into the Reisa river, which is directly related to the river flow. While we don't see a significant change in the number of heavy and extreme rainfall events at this time, the general pressure of increasing rainfall and snow-melt creates a very serious increase in the risk of the Reisa river flooding in spring (Figure 13).

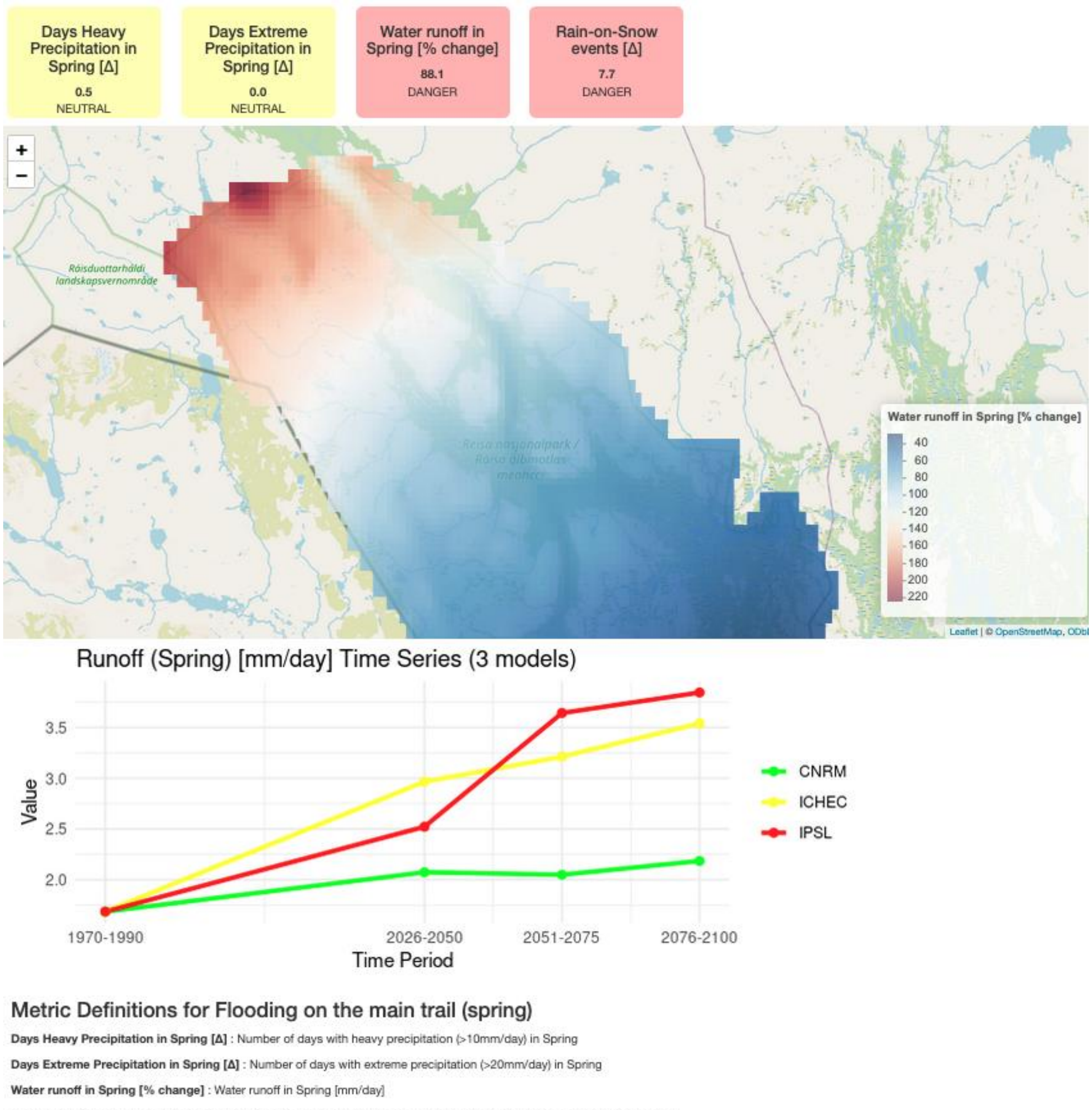

Figure 13. An overview of the risk of Flooding on the main trail in 2051-2075 under a mid-emissions scenario.

River summer access

Access to the Reisa river in summer is principally governed by the shifting patterns of rainfall. One of the paradoxes of how climate change affects summer conditions is that even though the amount of rainfall is expected to increase, the amount of runoff into the Reisa river is projected to decrease. There are many reasons for this to be the case. As the atmosphere warms, more water is evaporated from the soil into the air before it runs off into the river. We also see a reduction in the number of drought days and consecutive dry days, meaning that the soil stays moist and able to absorb more water. In a mid-emissions scenario these competing processes result in a dramatic reduction in water runoff of about 40%. However, as we go further into the future, or we look at higher emissions scenarios, we find the effect of increasing rainfall dominates again, and runoff increases. This is a clear example of climate change being non-linear and that more warming doesn't necessarily translate to more change in a given climate metric (Figure 14). Overall, there is a serious threat to summer access to the Reisa river due to reduced water flow.

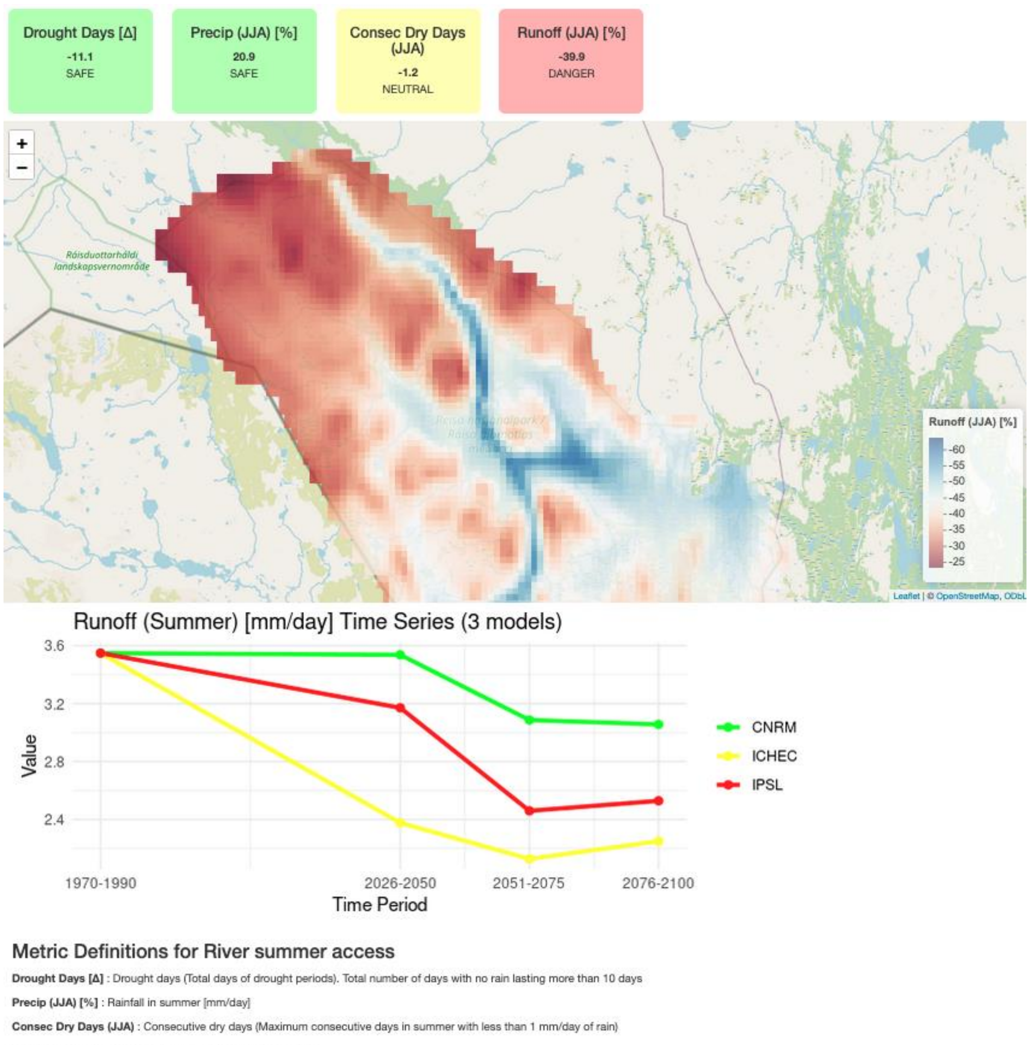

Figure 13. An overview of the risk of Flooding on the main trail in 2051-2075 under a mid-emissions scenario.

Summary and recommendations

This assessment provides a clear and actionable overview of the projected climate risks facing Reisa National Park. Through a collaborative process with park managers, we identified six key priorities and explored how each may be impacted by changes in temperature, precipitation, snow cover, and seasonality.

Key findings:

- **Spring Flooding** poses the most significant and consistent risk across all scenarios, with projections showing an expected doubling of runoff and rain-on-snow events. This will impact infrastructure, ecosystems, and visitor safety.
- **River Winter Access** is expected to decline substantially, with the period of safe frozen river travel halving by mid-century due to warmer and shorter winters.
- **River Summer Access** is also at risk, with summer runoff projected to decline by ~40%, even in scenarios with increased rainfall. This paradox highlights the complex hydrological shifts occurring under climate change.
- **Atlantic Salmon** face moderate but increasing pressure due to declining river flow and warming conditions, though mid-century impacts are not yet severe.
- **Wildfire Risk** is not projected to increase under current scenarios, as increased summer rainfall and fewer drought days offset temperature-driven risks.

Recommendations for Reisa National Park Management:

1. **Prioritize Flood Management Planning:**
   - Update and expand spring flood contingency plans.
   - Invest in early-warning systems for river flooding and rapid runoff events.
   - Map vulnerable sections of the main trail and visitor infrastructure.
2. **Adapt Winter Access Strategies:**
   - Rethink dependence on frozen-river routes and develop alternative winter pathways.
   - Consider signage and monitoring to guide safe access based on real-time conditions.
3. **Prepare for Reduced Summer Water Availability:**
   - Monitor summer river flow trends and explore adaptive solutions for aquatic recreation and transport.
   - Assess implications for species dependent on cold-water habitats, particularly Atlantic salmon.
4. **Sustain Long-Term Monitoring and Tools:**
   - Continue using high-resolution, downscaled projections through tools like the Reisa web app.
   - Integrate updated data into management cycles and communicate changes with stakeholders.

This report and the interactive web tool should serve as living resources, supporting park managers in navigating an uncertain but increasingly knowable climate future. Continued dialogue between scientists and park staff will be key to transforming insight into action.