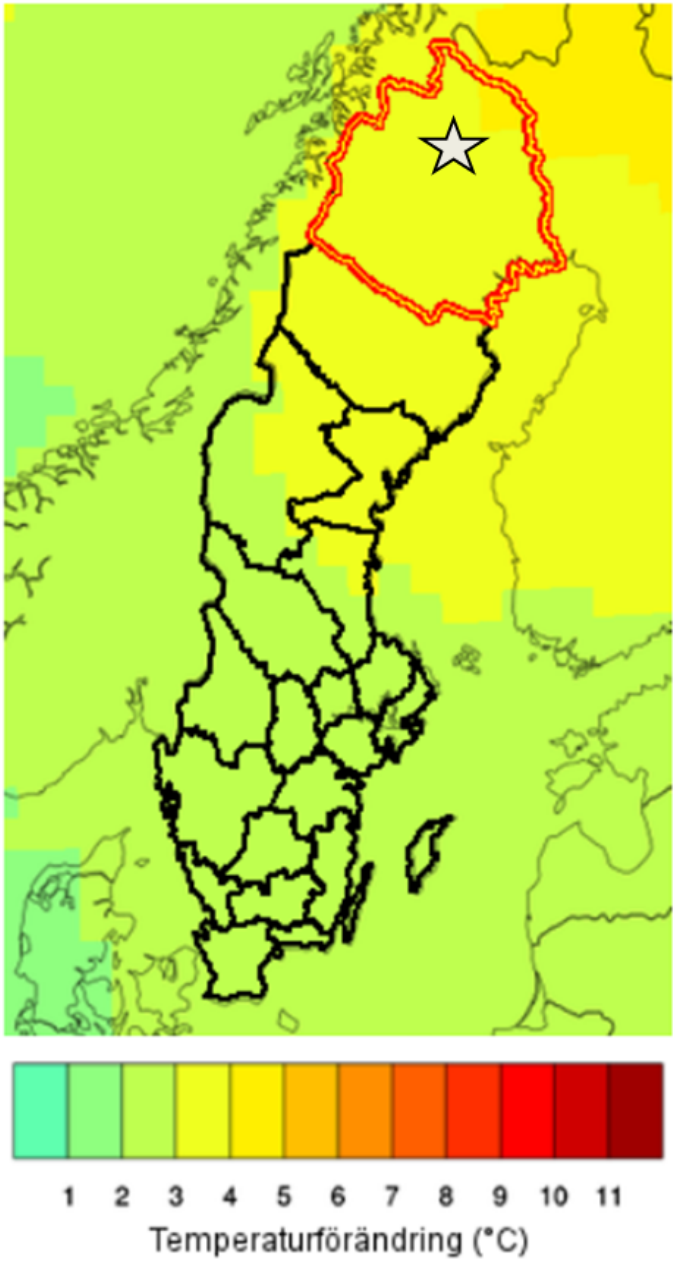


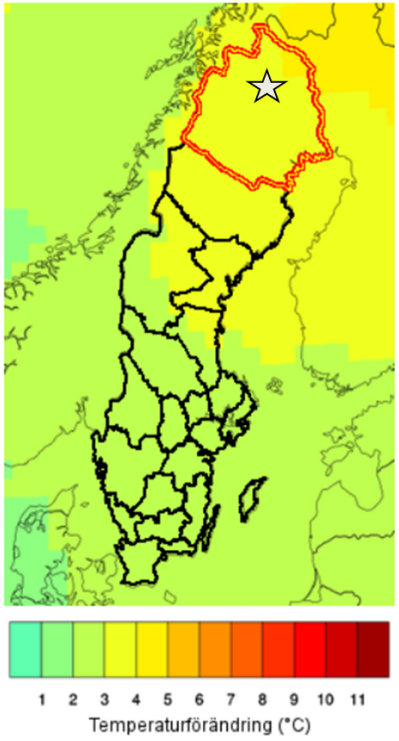
Climate Dataset: Aitik Closure Project

November 28th & 29th, 2018

NEW BOLIDEN

Climate Dataset: Aitik Closure Project

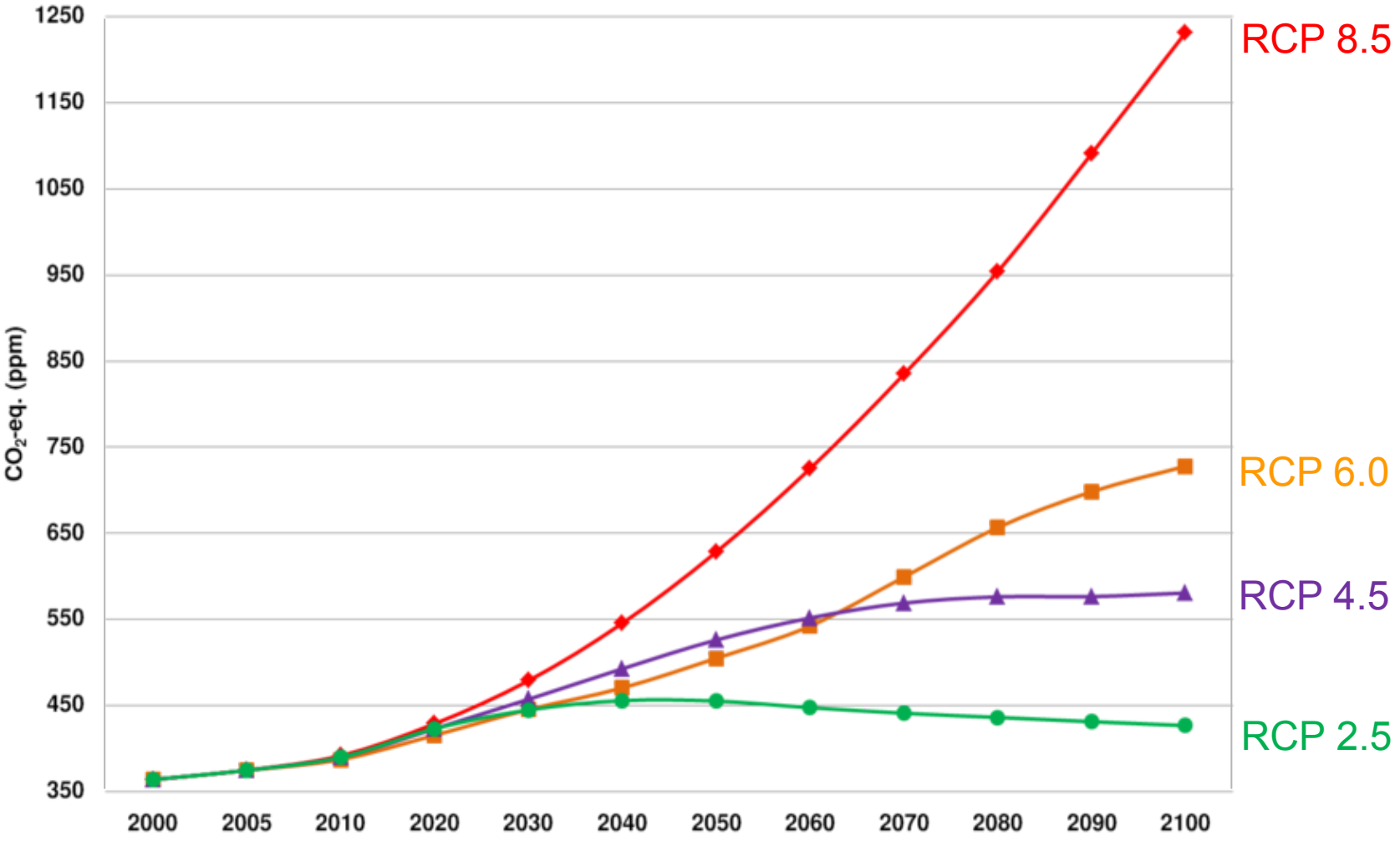
- Early in the Closure Project, consensus was reached to assemble a long-term daily climate dataset for input to the various sub-tasks within the closure project.
- All sub-tasks within the project would utilize the climate dataset to provide the basis for consistent results and reporting.
- Climate dataset needed to be robust. It could not simply be a historical dataset adjusted with a consistent temperature or precipitation increase to account for climate change effects.
- The climate dataset needed to capture both the direction of change for key water balance variables (e.g. Temp., Precip.), as well, capture the full range of natural variability per parameter over the closure timeline
- The dataset needed to account for seasonality and provide daily data that could be used to produce monthly or annual values



Climate Dataset: Aitik Closure Project

- Climate dataset was based on proceedings of IPCC Fifth Assessment Report and produced by Swedish Meteorological and Hydrological Institute (SMHI).
- Three emission scenarios (representative concentration pathways (RCP)) considered:
  - RCP 2.6: Powerful climate politics cause greenhouse gas emissions to peak in 2020. The radiative forcing will reach 2.6 W/m² by the year 2100.
  - RCP 4.5: Strategies for reducing greenhouse gas emissions cause radiative forcing to stabilize at 4.5 W/m² before the year 2100.
  - RCP 8.5: Increased greenhouse gas emissions mean that radiative forcing will reach 8.5 W/m² by the year 2100.

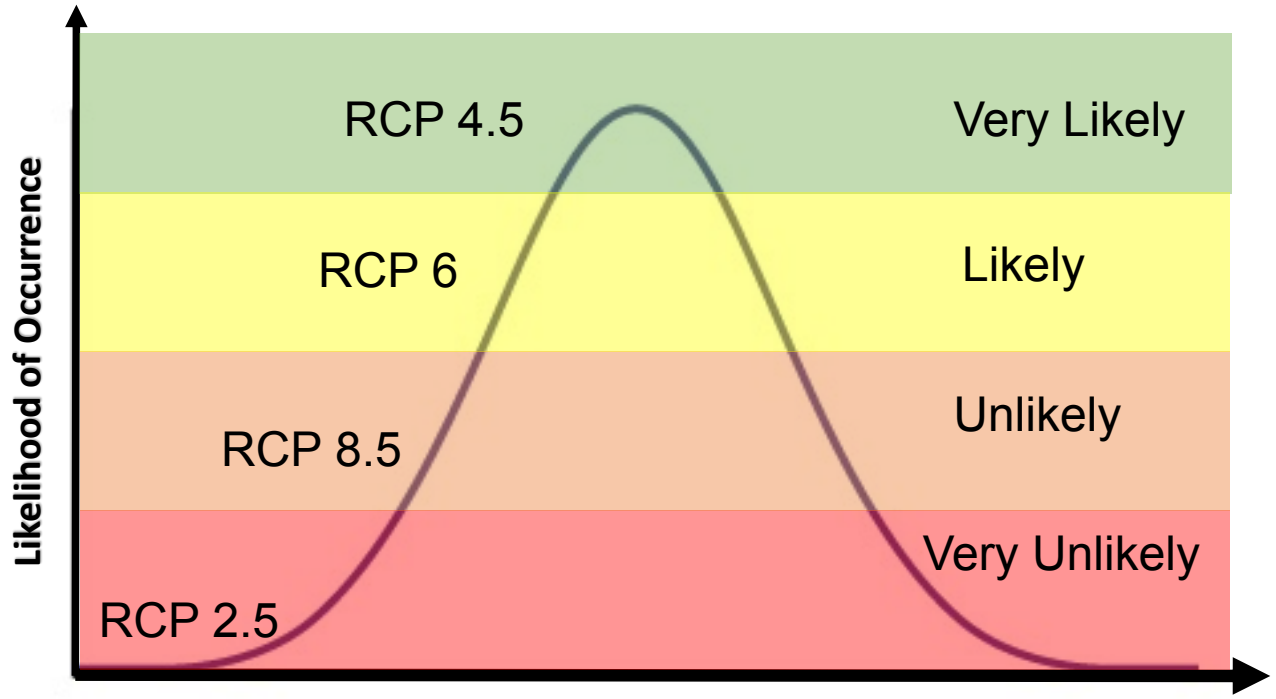
Climate Change Scenarios



NEW BOLIDEN

Likelihood of Occurrence

- IPCC does not provide RCP probability
- Need to Rank RCP's based on project risk profile

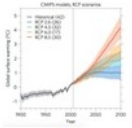


Likelihood is project/time specific - depends on the accepted risk profile

BOLIDEN

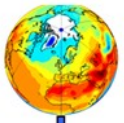
Climate Dataset: Aitik Closure Project

Climate Change Scenario



AR5: e.g., RCP4.5

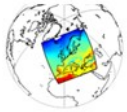
GCM



Global Climate Model (e.g., EC-Earth)

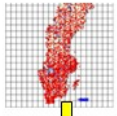
downscaling

RCM



Regional Climate Model (e.g., SMHI – RCA4)

Statistics



Bias-correcting, scaling as appropriate

Hydrology Modeling

SMHI, HYPE Model (Rivers and Creeks)

Aitik Mine Closure Plan: Flow and Water Quality Modeling

TMF Sub-models (Flow, seepage, chemistry)

WRSF Sub-models (Flow, chemistry; T1-T7, T6)

Pit Lake Sub-models (Flow, chemistry; two pits)

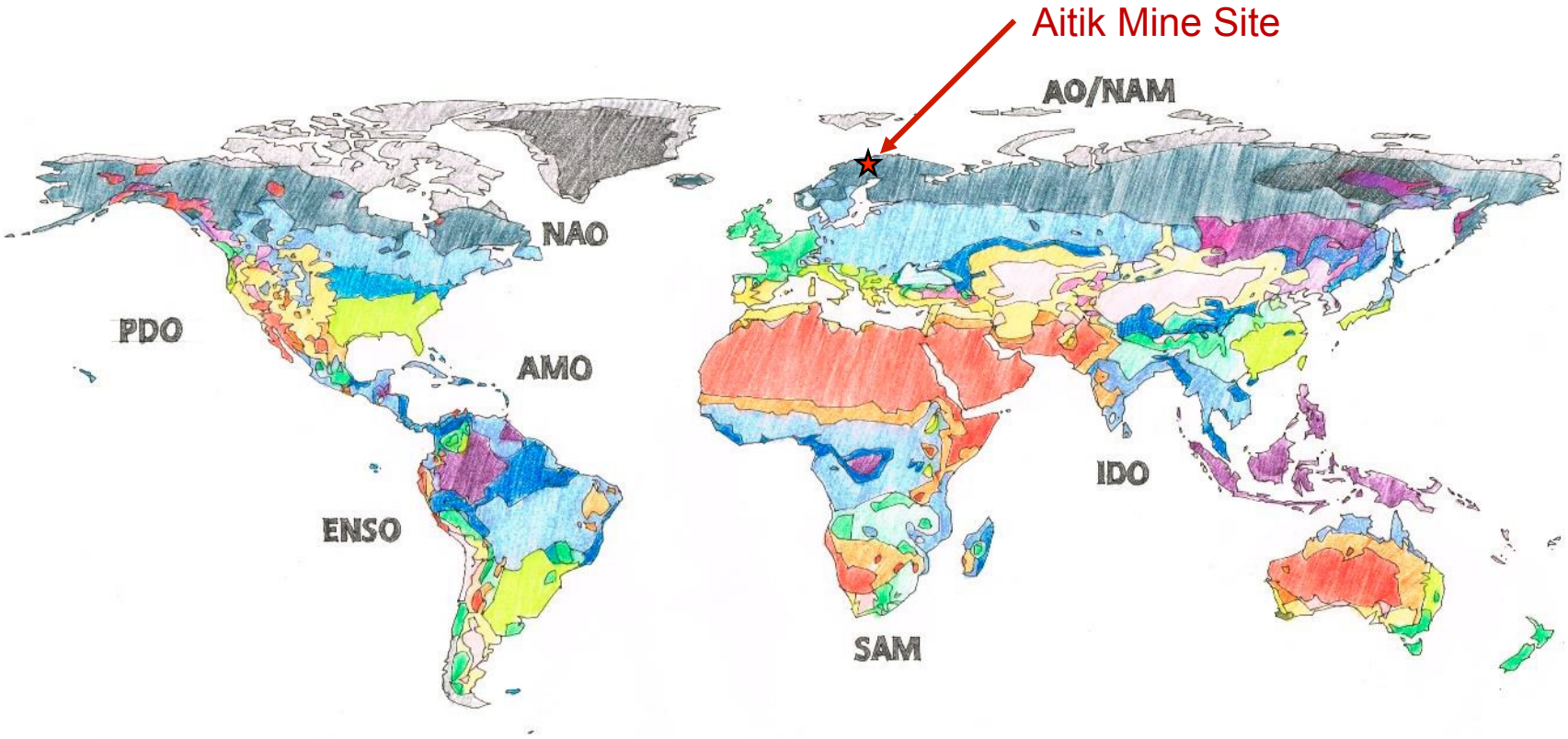
Flow Data Input: *Mine Site Discharge Data*

Flow Data Input: *Recipient Discharge Data*

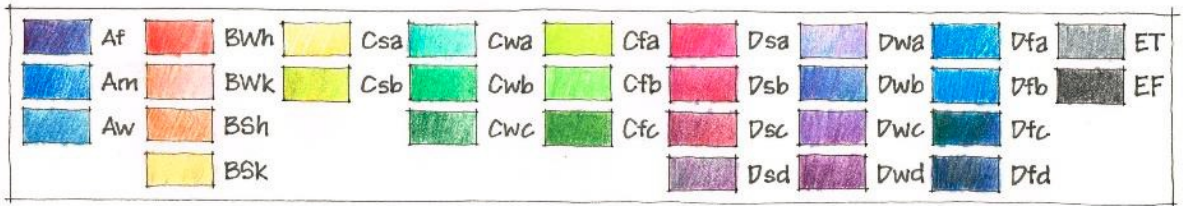
Recipient Water Quality Sub-model

NEW BOLIDEN

Regional Climate Classification



Köppen–Geiger climate classification system



Potential Climate Change Effects

- Aitik Mine is currently Dfc under the Köppen–Geiger classification system

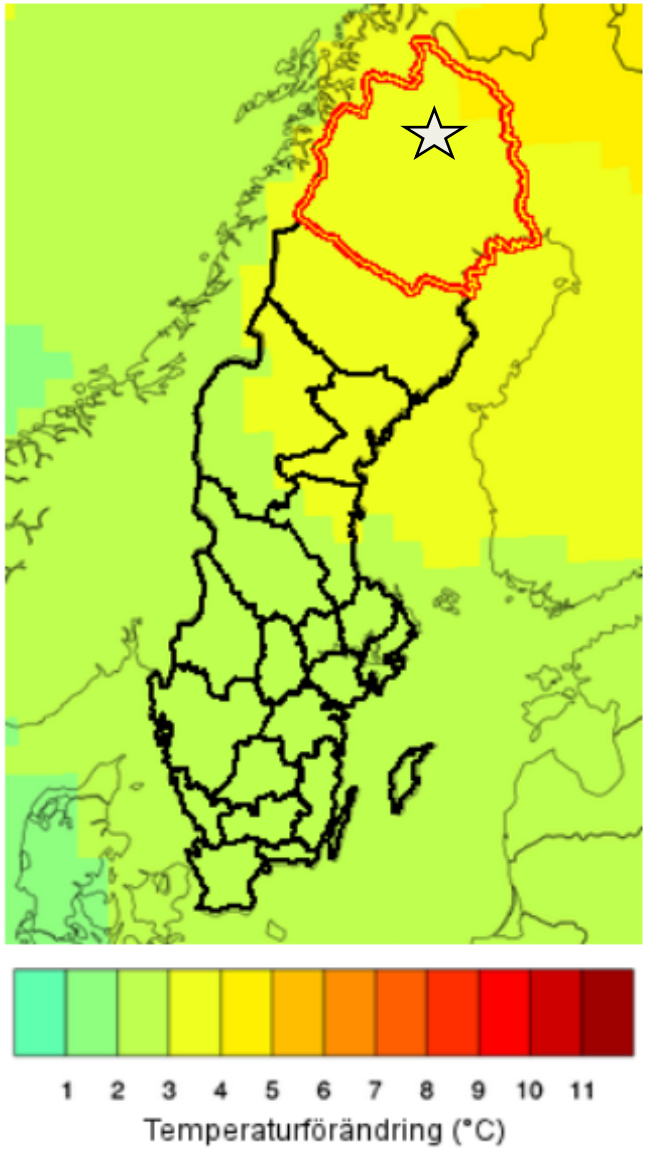
Continental subarctic or boreal (taiga) climate

- D = Cold (temperature of the hottest month greater than 10°C and the temperature of the coldest month is less than 0°C)
- f = Without a distinct dry season
- c = Cold summer

Expected to change to Dfb for the 2076-2100 period under RCP 4.5 scenario

- b = Warm summer (>4 months with average temperature greater than 10°C)

Potential Climate Change Effects

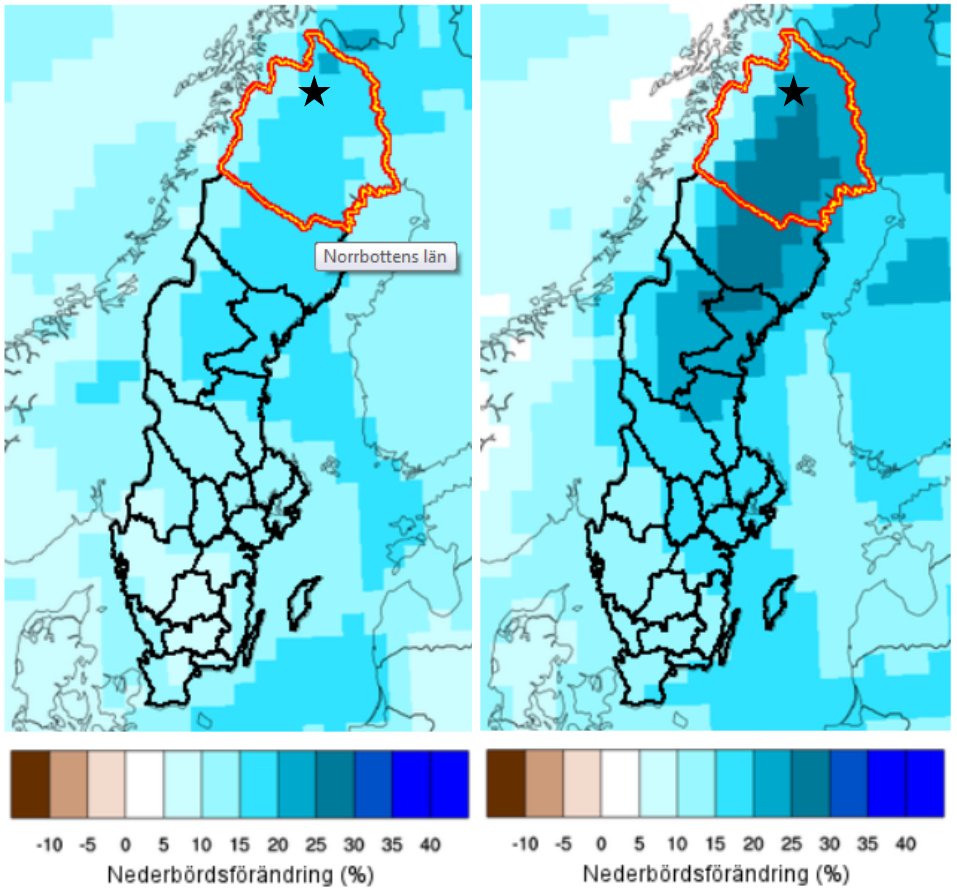


- Spring and fall traditionally are short transition seasons
  - Freeze-up is rapid
  - Occurrence of freezing rain uncommon
- Changing climate will result in longer summers and increase evaporation during frost-free period
- Changing climate will lengthen transition seasons so that freeze and thaw cycles become more common

Potential Climate Change Effects

Overall, the northern latitudes will be within what is referred to as a “hot spot” for climate change

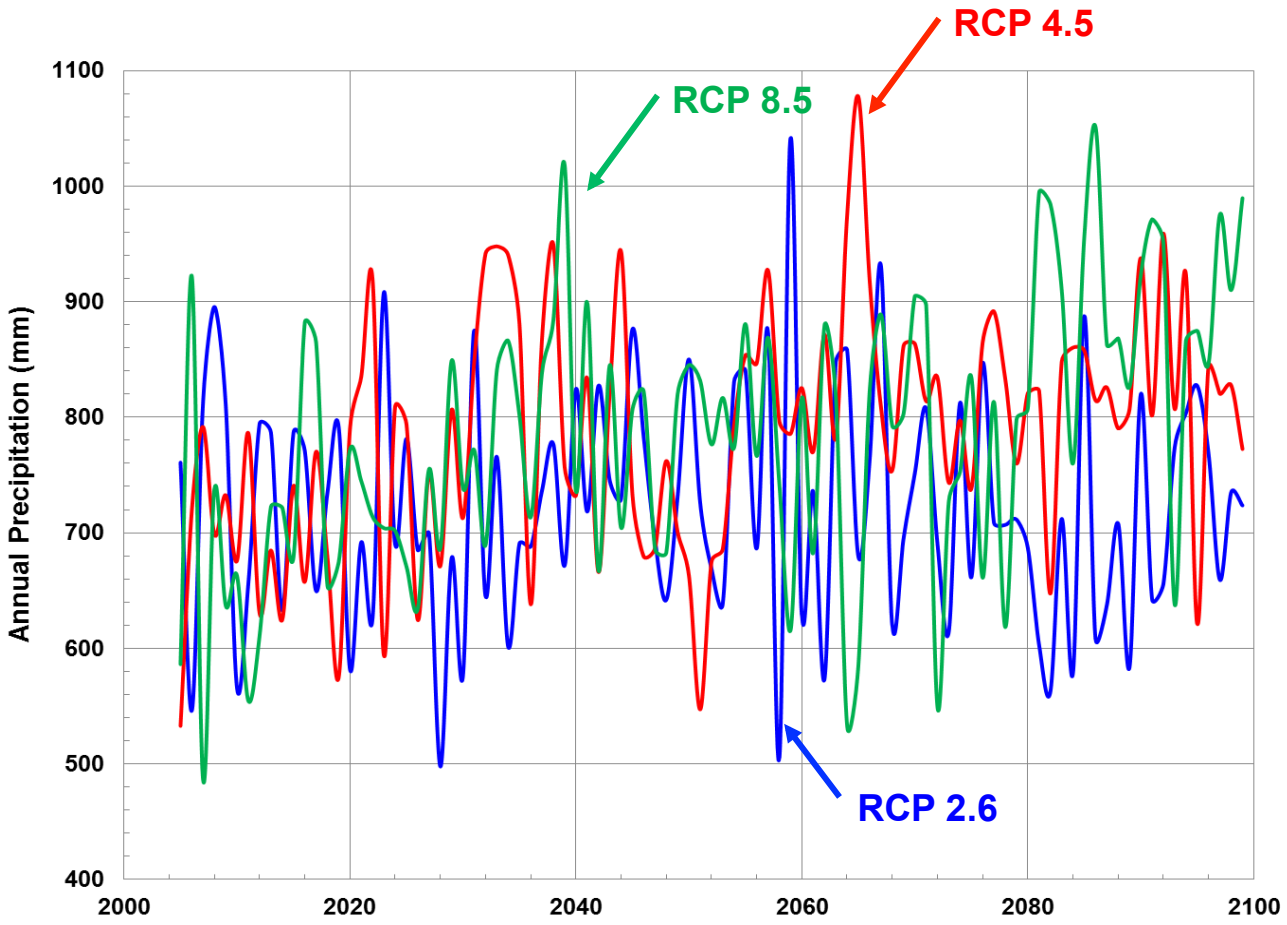
- Annual precipitation is predicted to increase by up to 20% over the next century; however, these changes will vary seasonally
- Amount and timing of precipitation becoming more highly variable between seasons
- For example, in the winter season snow cover period may be substantially reduced and snow may be replaced by rain or freezing rain in early spring and autumn.



Climate Dataset: Aitik Closure Project

- Projections of air temperature and precipitation for northern Sweden show a warmer and wetter future is likely.
  - Parameters included, but were not limited to, precipitation, runoff, temperature, relative humidity, wind speed, and net radiation
- Air temperature projections for the period 1960 to 2100 show a 4 to 5°C increase in annual air temperature for the RCP 4.5 scenario.
- On a seasonal basis, temperature change and climate variability are expected to be largest for the winter.
- Precipitation projections for the period 1960 to 2100 show a ~25% increase in annual precipitation for the RCP 4.5 scenario.

Climate Dataset: Aitik Closure Project



Recent (1998-2013) Gällivare average precipitation = 620 mm/yr

Long-term MAP

RCP2.6
~725 mm

RCP4.5
~800 mm

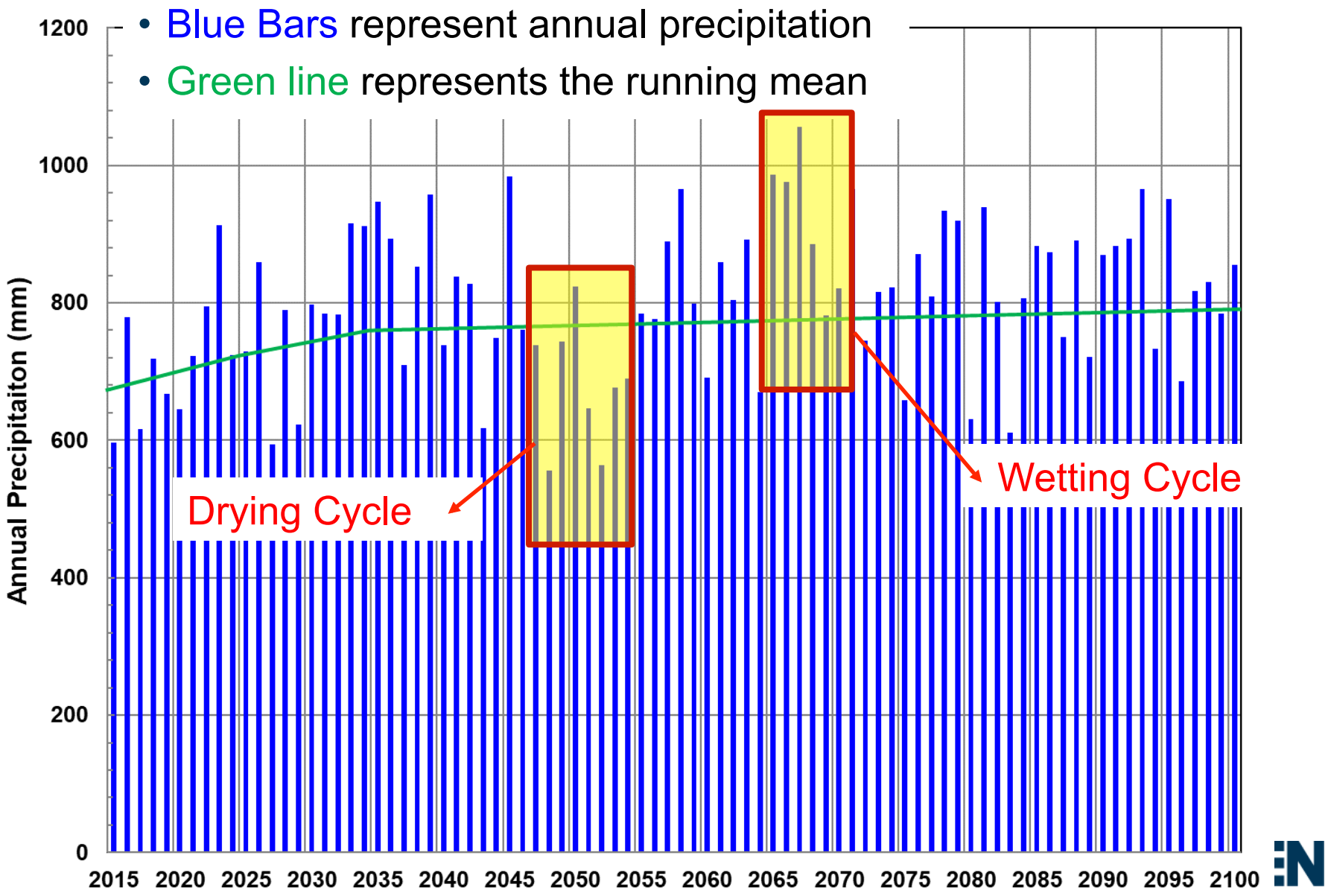
RCP8.5
~830 mm

Annual Variability

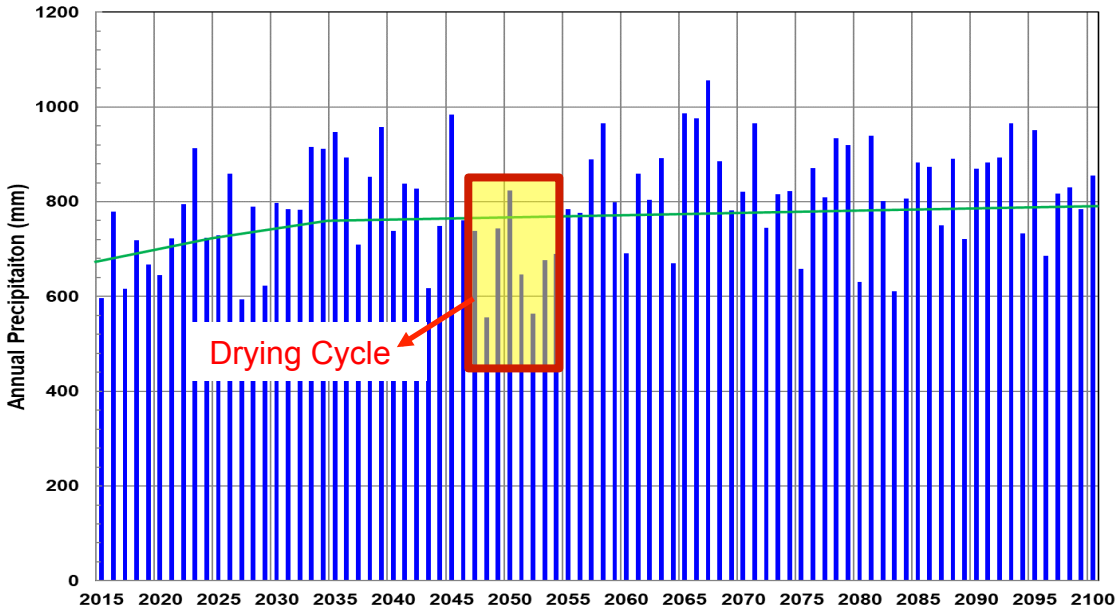
500 to 1,050 mm

- The assembled climate dataset inherently considers a wide range of scales of variability
- All numerical modelling conducted for the project includes this variability, which occurs over the time period, including large scale long term trends as well as smaller scale short duration cycles

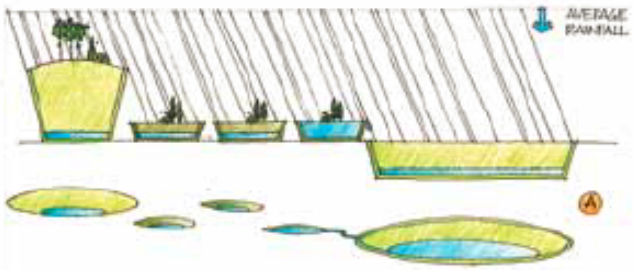
Climate Dataset: Illustrating Variability

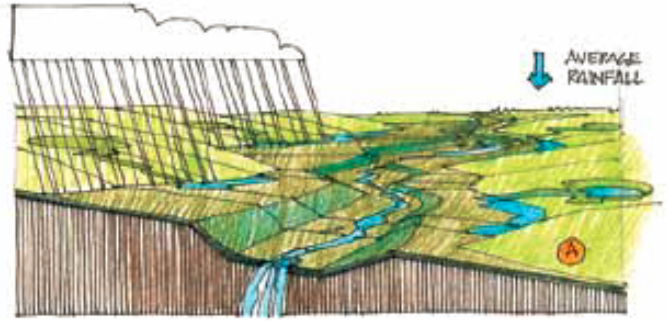


Climate Dataset: Illustrating Variability

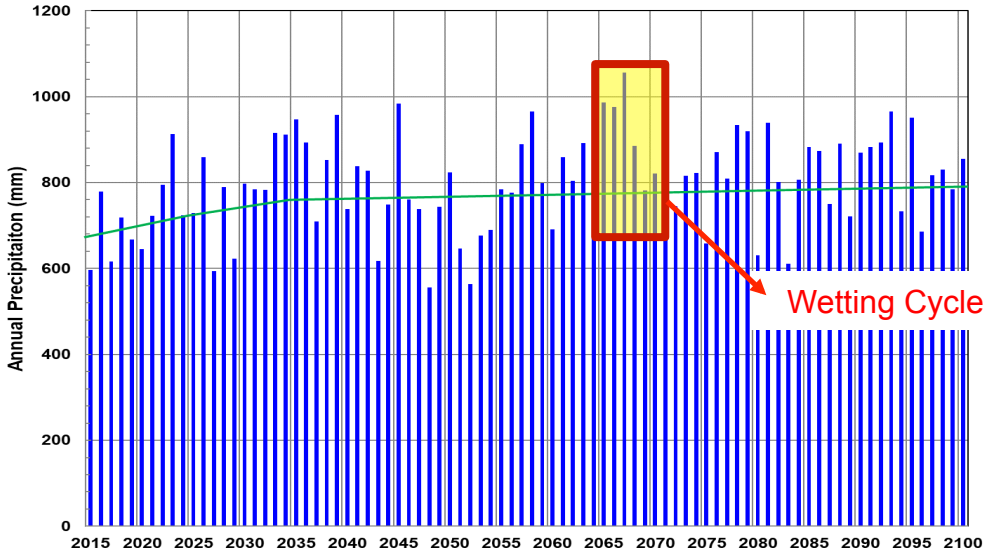


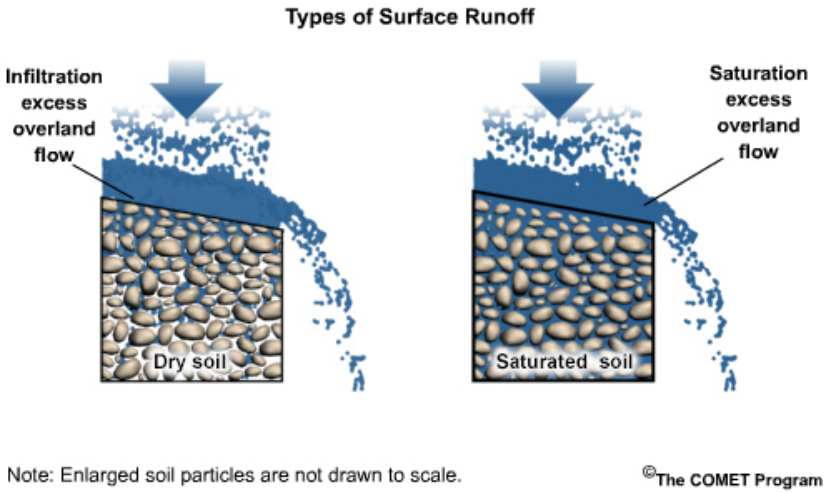
Drying Trend



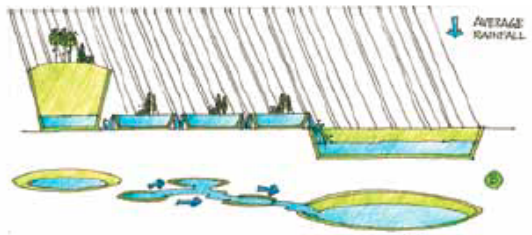


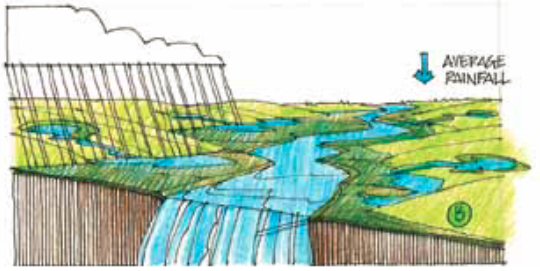
Climate Dataset: Illustrating Variability



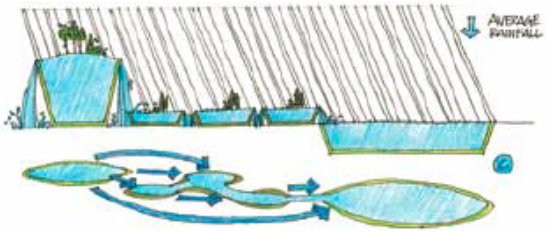


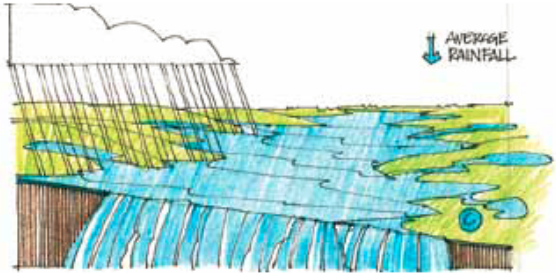
Wetting Trend following Drying





Wetting Trend following Wetting



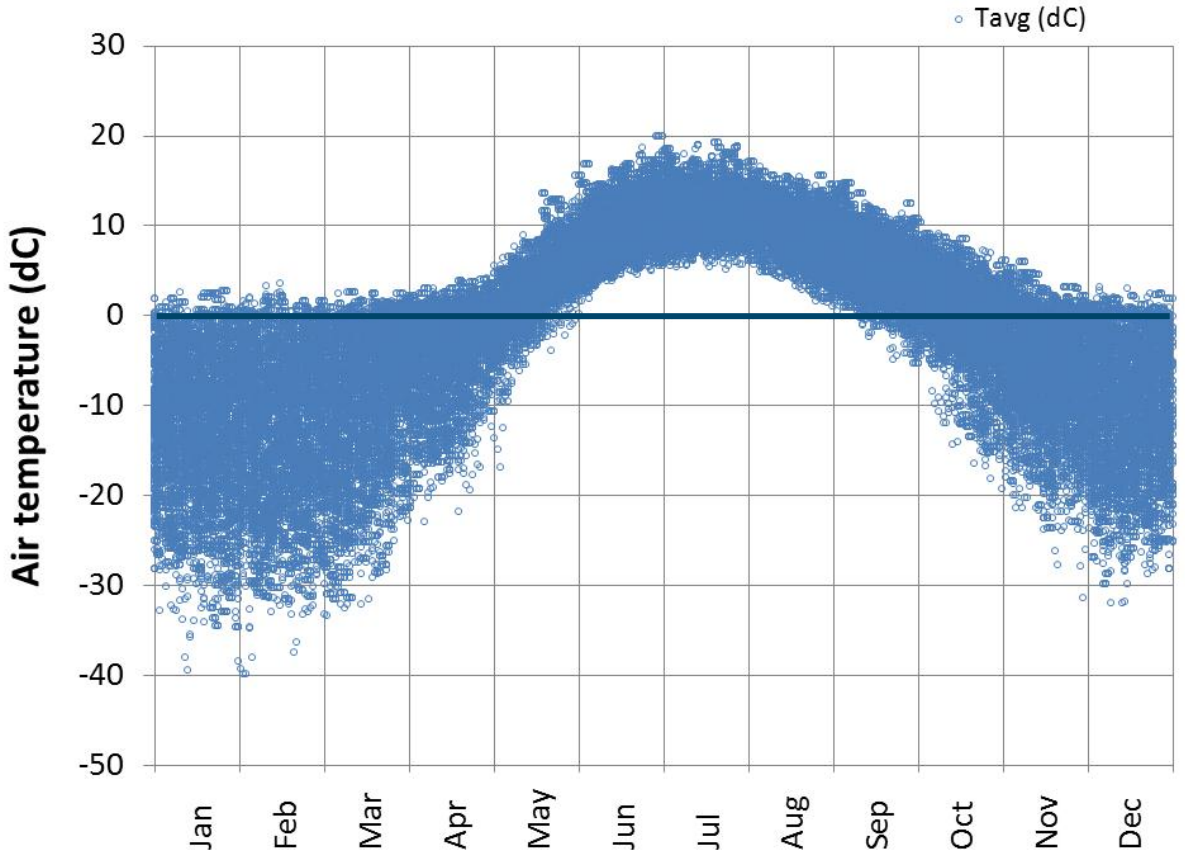


Climate Dataset: Aitik Closure Project

- Daily climate dataset was created by SMHI for the 2015-2100 period. Data from 2065-2100 was looped to create at database to 2200.
- All sub-tasks under the closure project would utilize the climate dataset to provide the basis for consistent results and reporting.
- The dataset was robust and accounted for seasonal changes rather than a broad increase / decrease to the climate variables
- The dataset provides daily data, if monthly or annual data was required the daily data was ‘rolled up’ to preserve the potential variation within the dataset
- When evaluating climate change…. its not just about the direction of change…. its also important to test the closure plan against the full range of climate variability, including annual and decadal wet/dry cycling

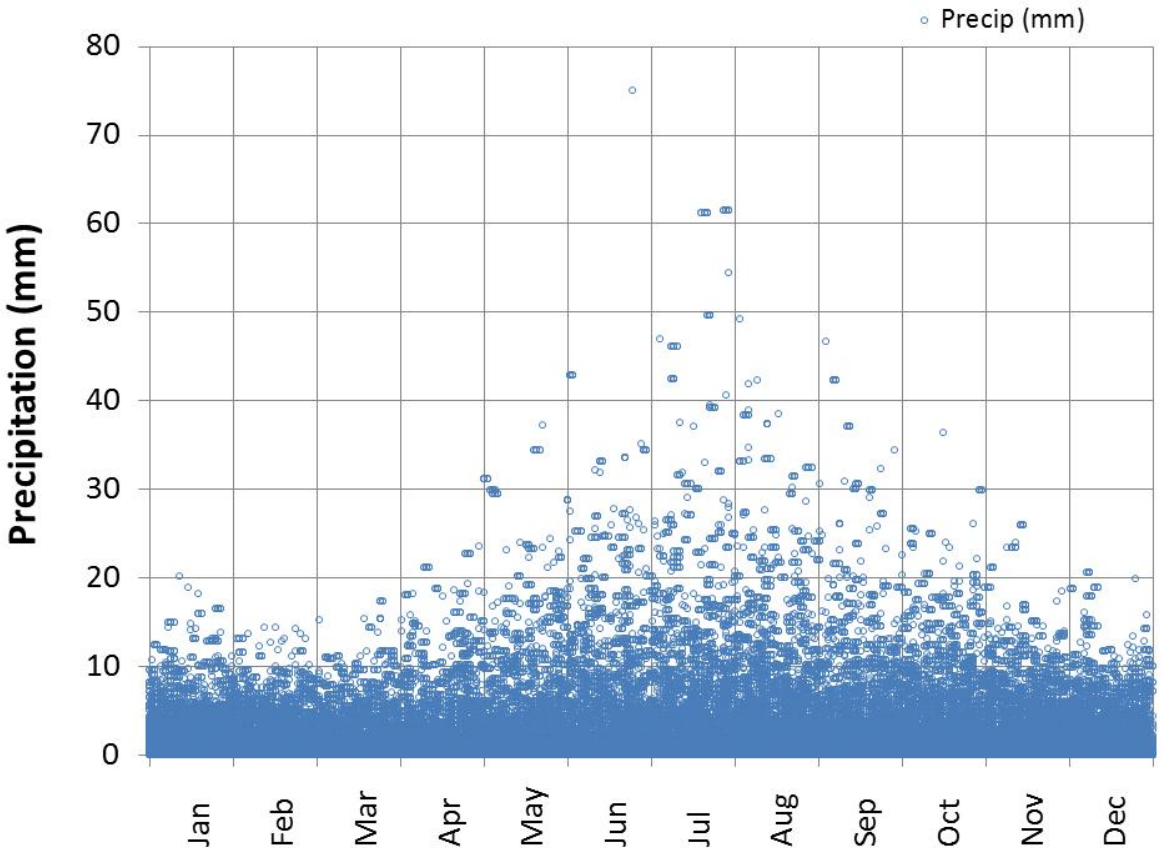
Climate Dataset: Aitik Closure Project

Daily air temperature observations for the climate dataset
Daily data for all years from 2015-2100.



Climate Dataset: Aitik Closure Project

Daily precipitation observations for the climate dataset.



BOLIDEN

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