Drought impacts on Prairie land surface hydrological dynamics

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Prairie hydrology of 1999-2005 drought

- Hydrology of the Canadian prairies is unique
- Dominated by small streams and wetlands which are ungauged
- Evaluation of hydrological effects of 1999-2005 drought will require modelling
- Ordinary models are useless for prairie conditions

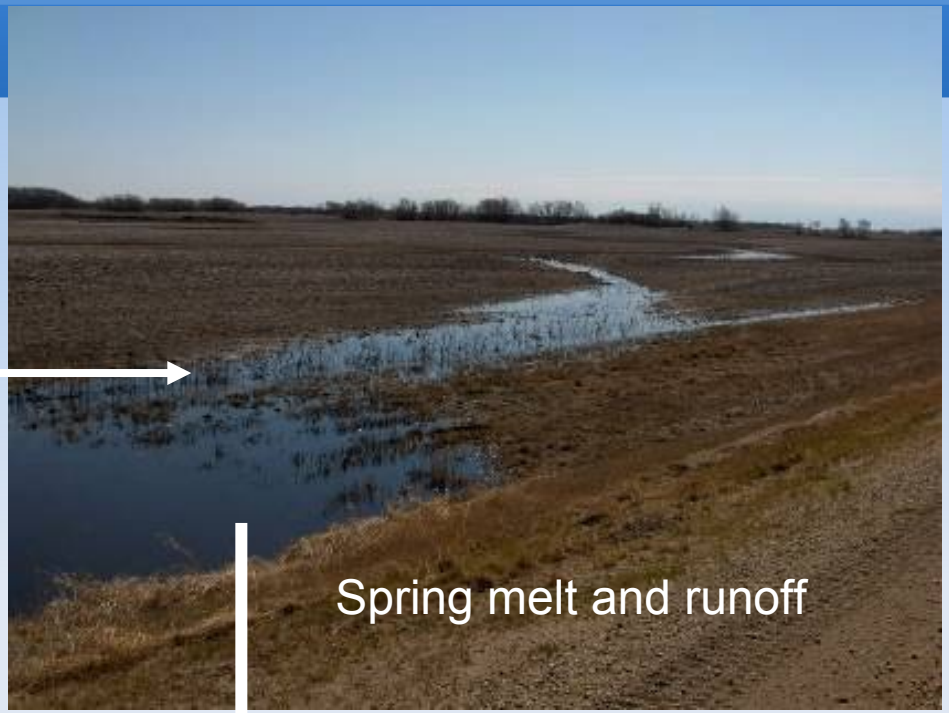
Future climate scenarios

- Hydrological effects of future climate are also unknown in prairies
- Models developed for this project will also be used to determine effects of future climate changes on prairie hydrology

Canadian Prairie Hydrology

- Wind redistribution of snow to wetlands and stream channels in winter is critical to formation of runoff contributing areas.
- Frozen soils enhance runoff efficiency during spring snowmelt so that >80% of runoff occurs during snowmelt period.
- Contributing area small and variable due to post glacial topography, large depressional storage potential and lack of a well developed fluvial drainage network.
- Baseflow from groundwater often nonexistent due to heavy glacial till substrate.
- Drainage of small streams and wetlands ceases completely in summer when actual evapotranspiration consumes most available water.
- Prairie streams are almost completely ungauged and often altered by dams, drainage, water transfers, etc.

Prairie Runoff Generation



Modelling Prairie Hydrology

- Need a physical basis to calculate the effects of changing climate, land use, wetland drainage
- Need to incorporate key prairie hydrology processes: snow redistribution, frozen soils, spring runoff, wetland fill and spill, non-contributing areas
- Hydrological models developed elsewhere do not have these features and fail in this environment
- Streamflow calibration does not provide information on basin non-contributing areas and is not suitable for change analysis

Cold Regions Hydrological Model Platform: CRHM

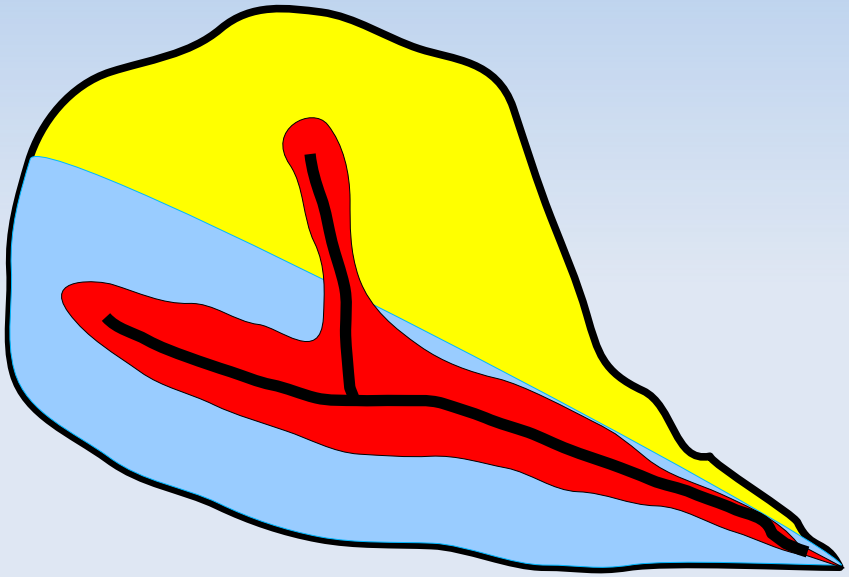
- Modular – purpose built from C++ modules
- Modules based upon +45 years of prairie hydrology research at Univ of Saskatchewan
- No provision for calibration or optimization, parameters set by knowledge
- Hydrological Response Unit (HRU) basis
  - landscape unit with characteristic hydrological processes
  - single parameter set
  - horizontal interaction along flow cascade matrix
  - Model tracks state variables and flows for HRU
- HRUs assumed to represent one response type, basis for coupled energy and mass balance
- HRUs connected aerodynamically for blowing snow and via dynamic drainage networks for streamflow
- Incorporate wetlands directly using fill and spill algorithm

“Virtual” basins

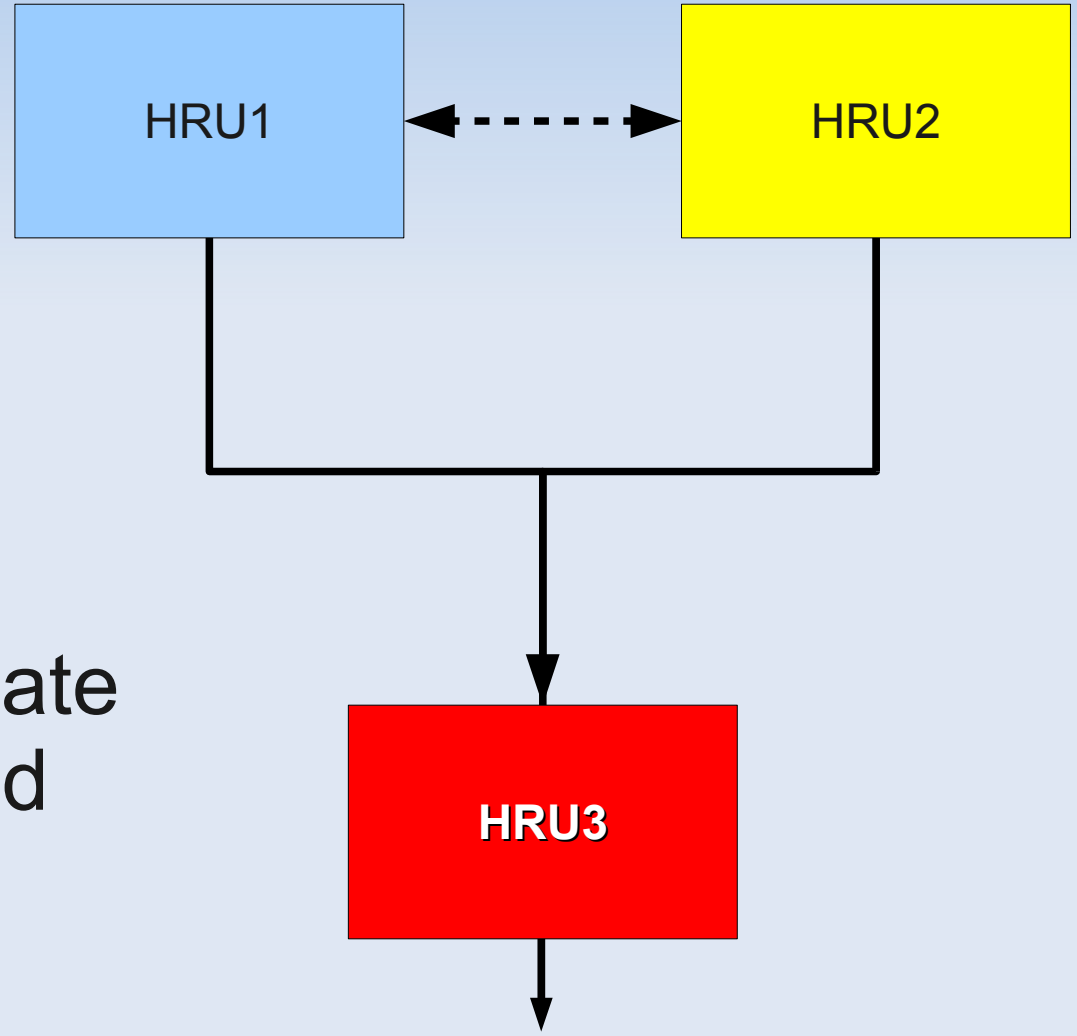
- The spatial variability of the drought will be simulated using models of two typical prairie basins:
  1. a small upland stream, and
  2. a small wetland complex
- The virtual basins will be simulated all over the praries, wherever sets of forcing variables are available
- Outputs during the drought period will be compared to the climate normal period of 1961-1990

CRHM model of small prairie stream basin

Small stream basin



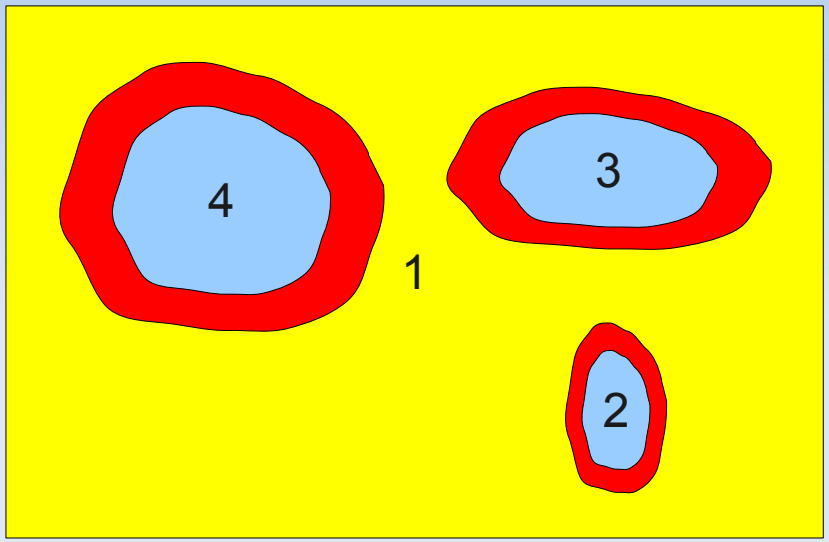
CRHM model



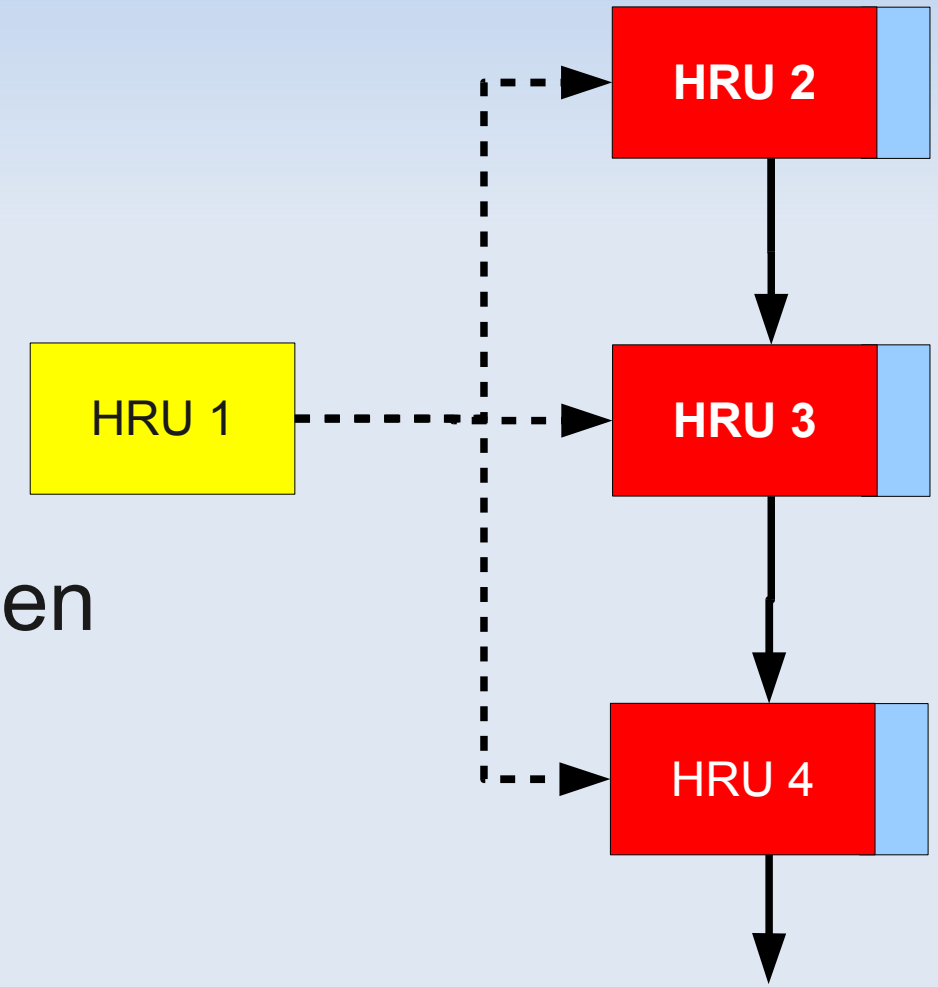
- HRUs 1 and 2 alternate between cropped and fallow
- HRU3 is grassed

CRHM model of small prairie wetland

Small wetland complex



CRHM model



- HRU 1 alternates between cropped and fallow
- HRUs 2-4 are wetlands

CRHM data requirements

- CRHM requires only a few variables:
  - Daily
    - Snowfall
  - Hourly
    - Rainfall, Air temperature, RH,Windspeed, Solar radiation
- Solar radiation required for modelling snow melt, evaporation and other processes
  - Currently, measurements are only available at Regina

Simulated Data

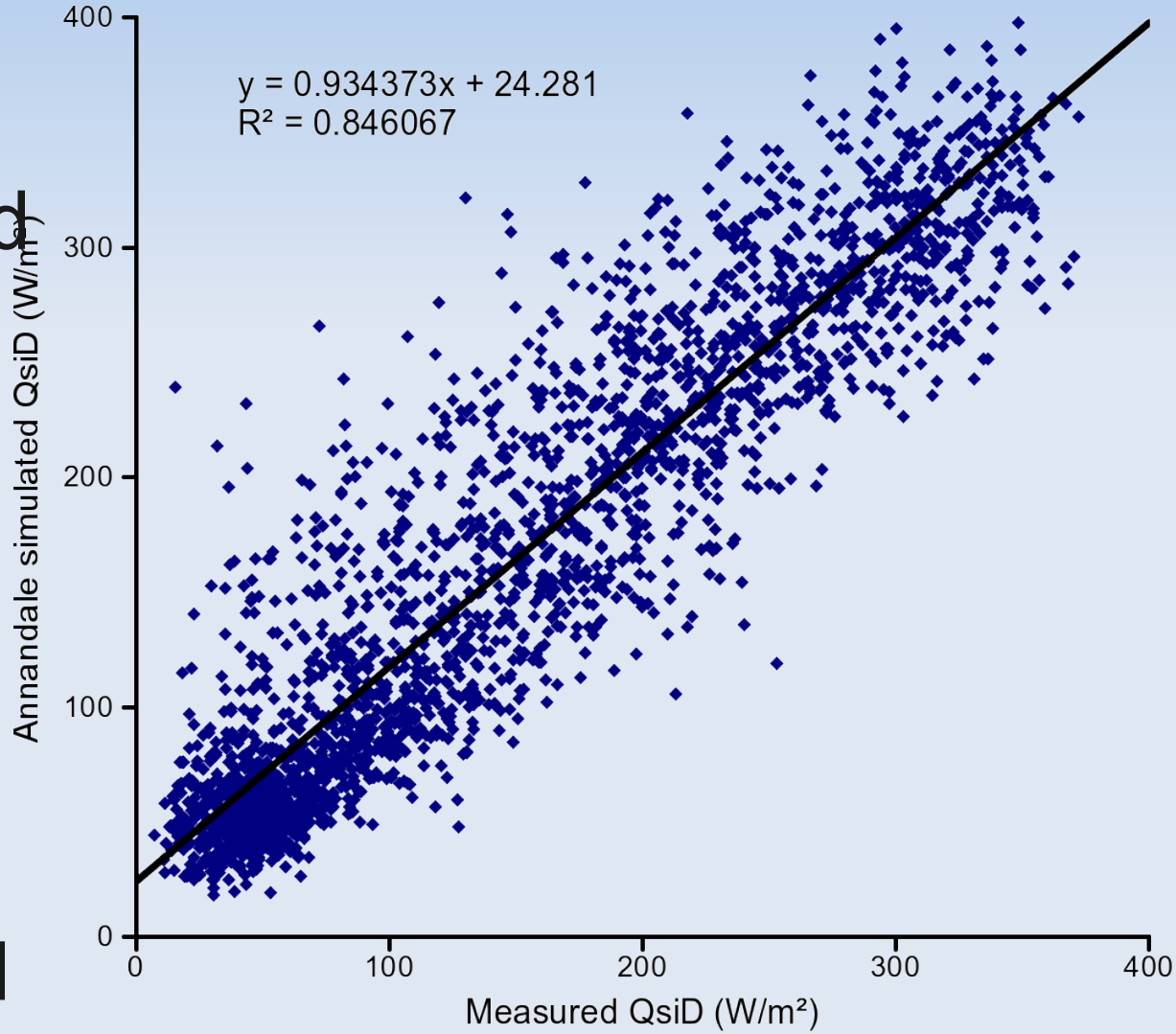
- NARR
  - Available as daily or 3-hour values
  - 32 km grid
  - All required variables available, since 1979
  - Free!
- but
  - Canadian precipitation data not assimilated by NARR
  - Windspeeds and precipitation are unusable

Estimation of Qsi

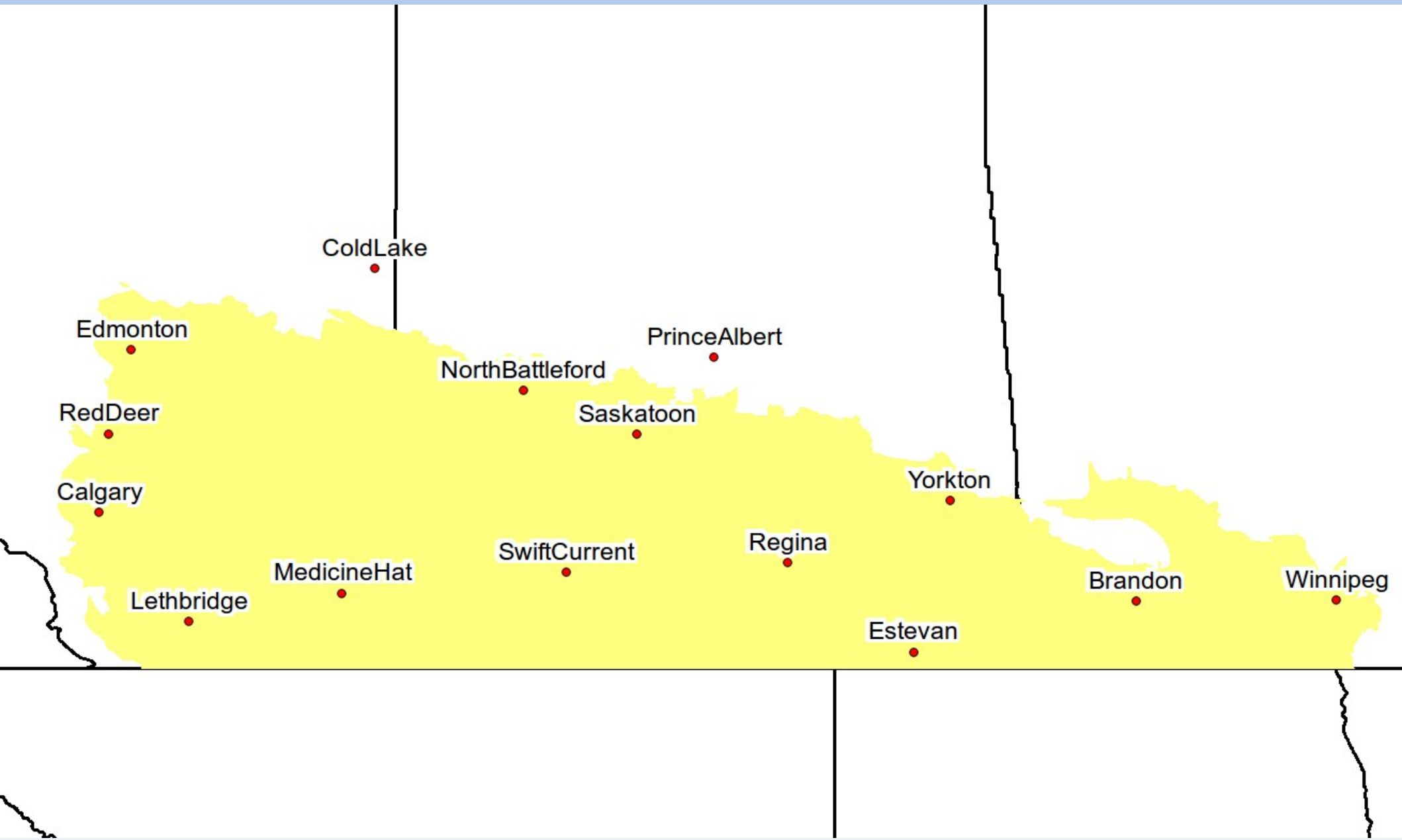
- Incoming short-wave radiation ($Q_{s\,i}$) can be calculated directly if the atmospheric transmittence is known
- Many researchers have found simple empirical relationships between daily atmospheric transmittance and the range of daily air temperatures (ΔT)
- Given the daily estimated $Q_{s\,i}$, CRHM can calculate the hourly components of the solar radiation (incoming, outgoing, shortwave and longwave)

Annandale Daily Qsi

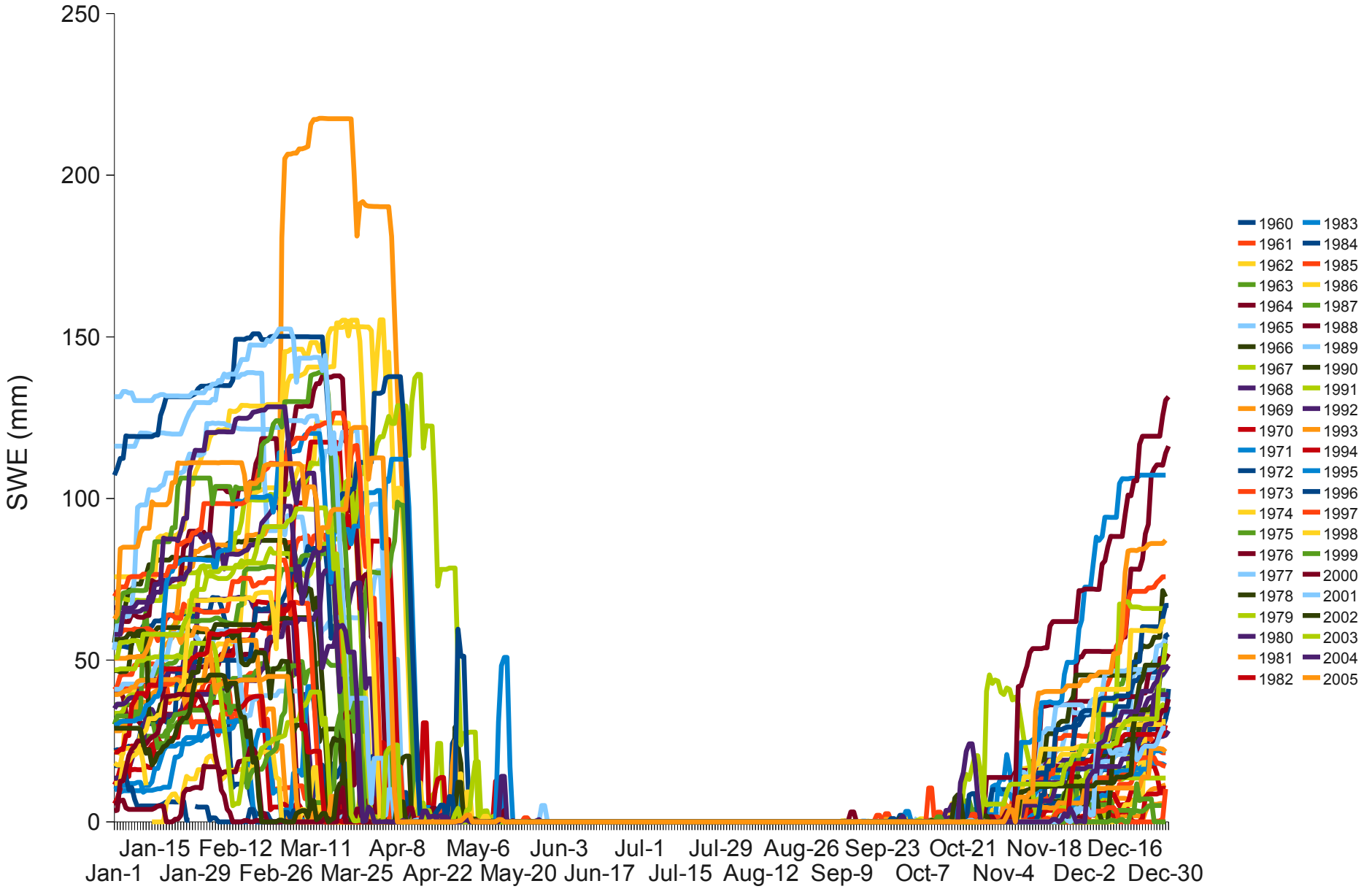
- Annandale method yields daily Qsi values about as good as NARR's
- Effects of scatter even out over a season
- Very simple to calculate
- Now built into CRHM



Sites


ColdLake
Edmonton
PrinceAlbert
NorthBattleford
RedDeer
Saskatoon
Yorkton
Calgary
Regina
SwiftCurrent
MedicineHat
Brandon
Winnipeg
Lethbridge
Estevan

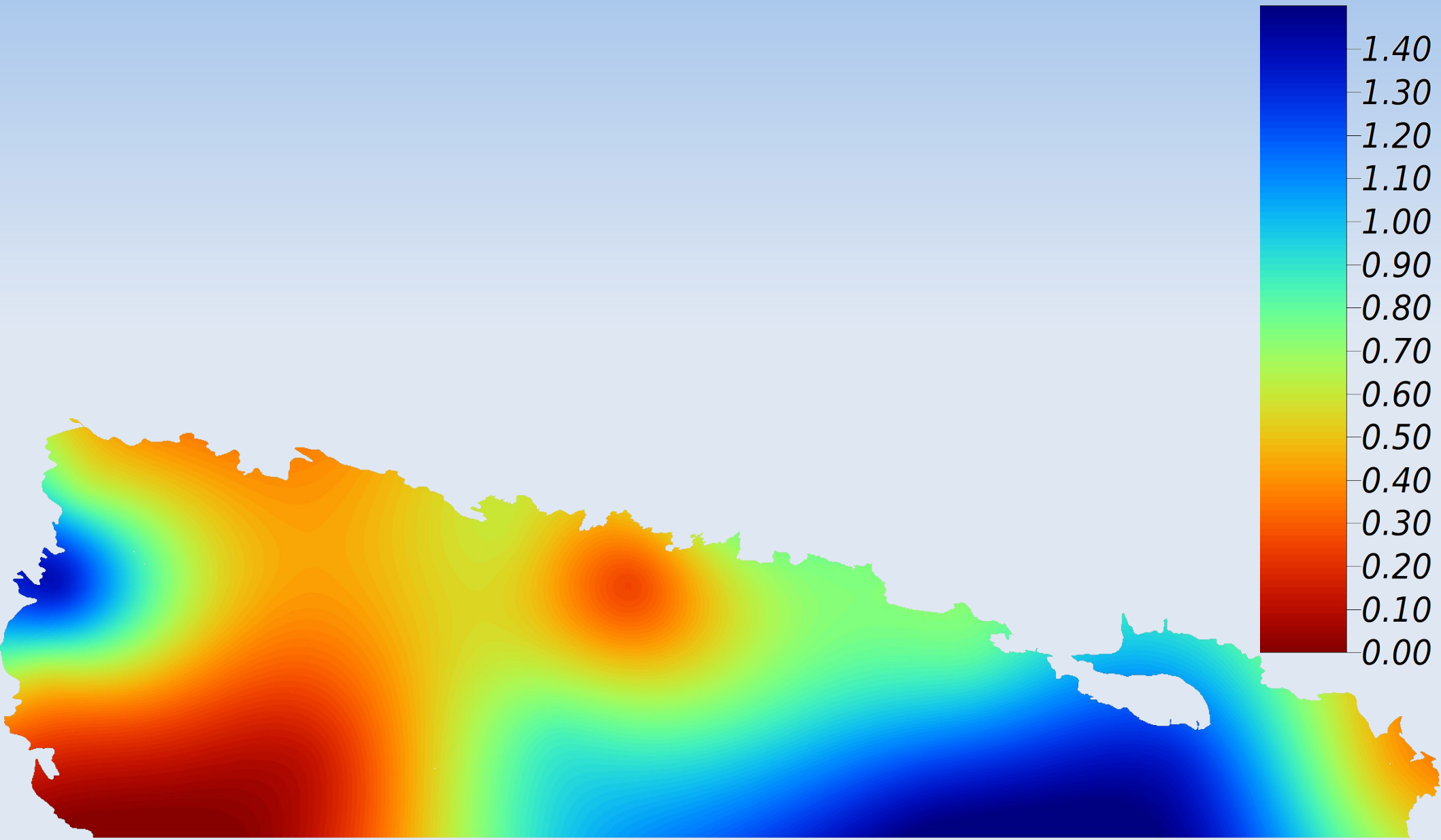
Brandon HRU1 SWE



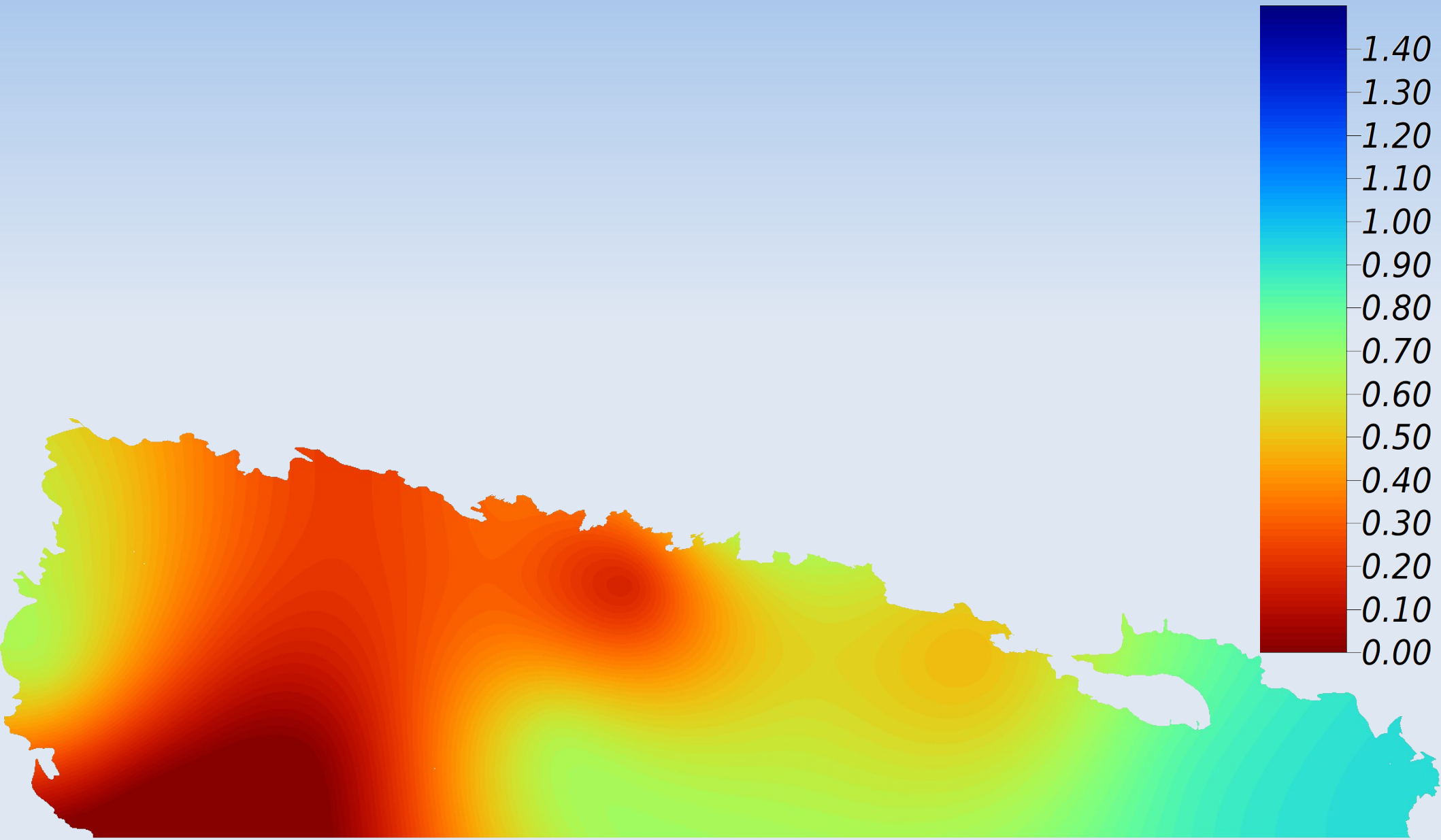
Gridded simulation results

- Drought period values divided by normals for ease of comparison
- Resulting values gridded (thin-plate spline) to show spatial variability

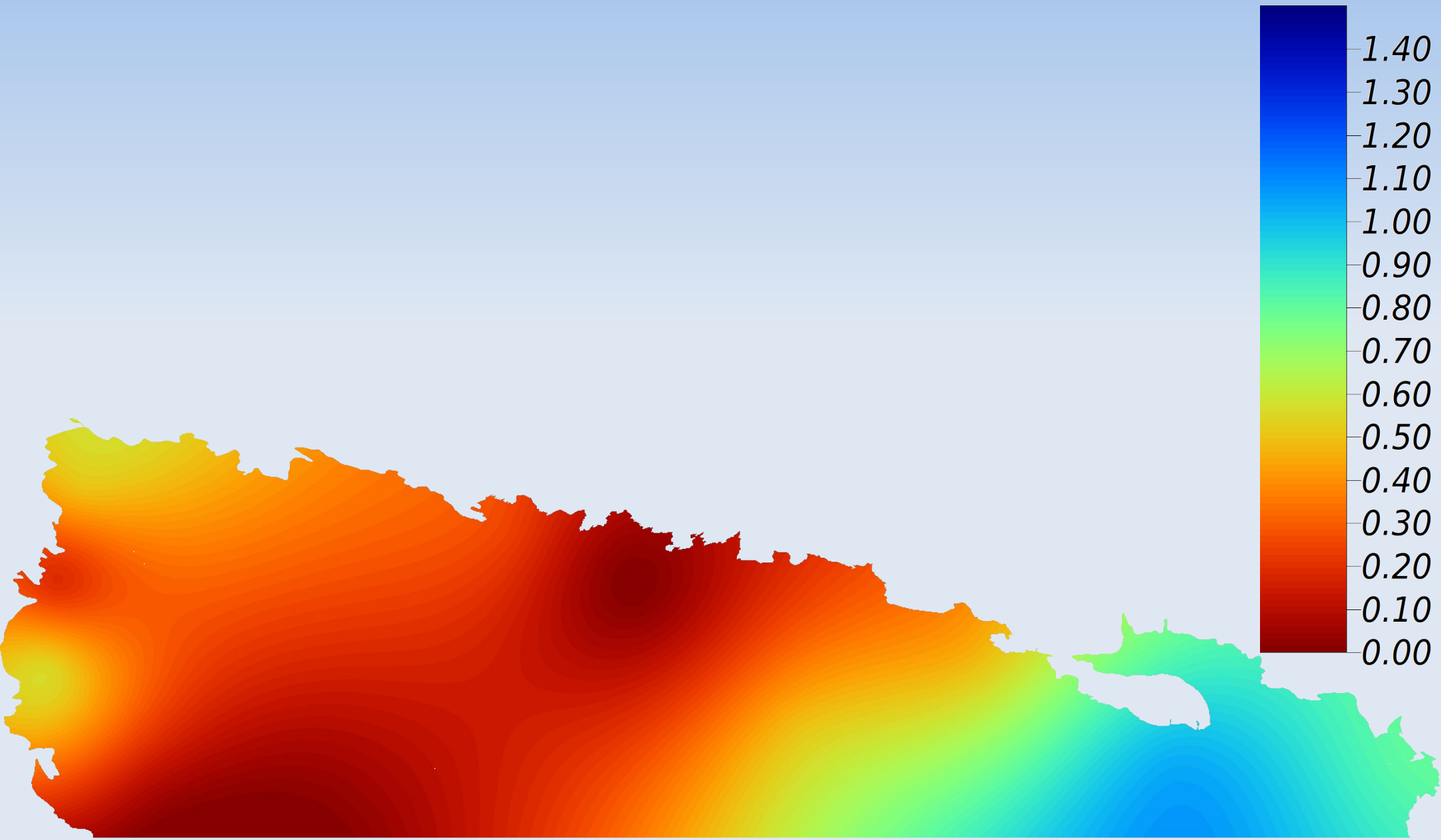
1999 Annual Discharge/Normal



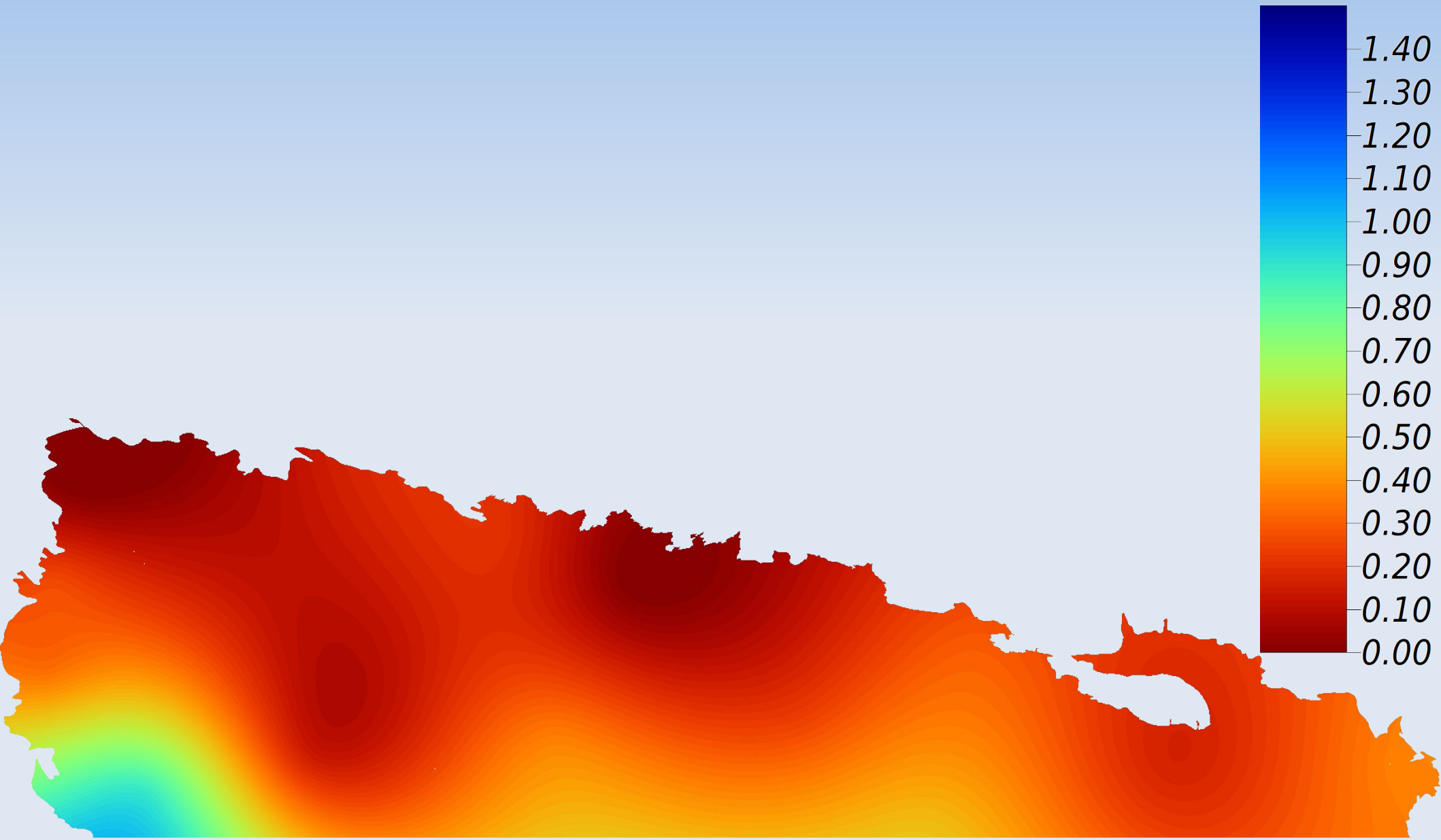
2000 Annual Discharge/Normal



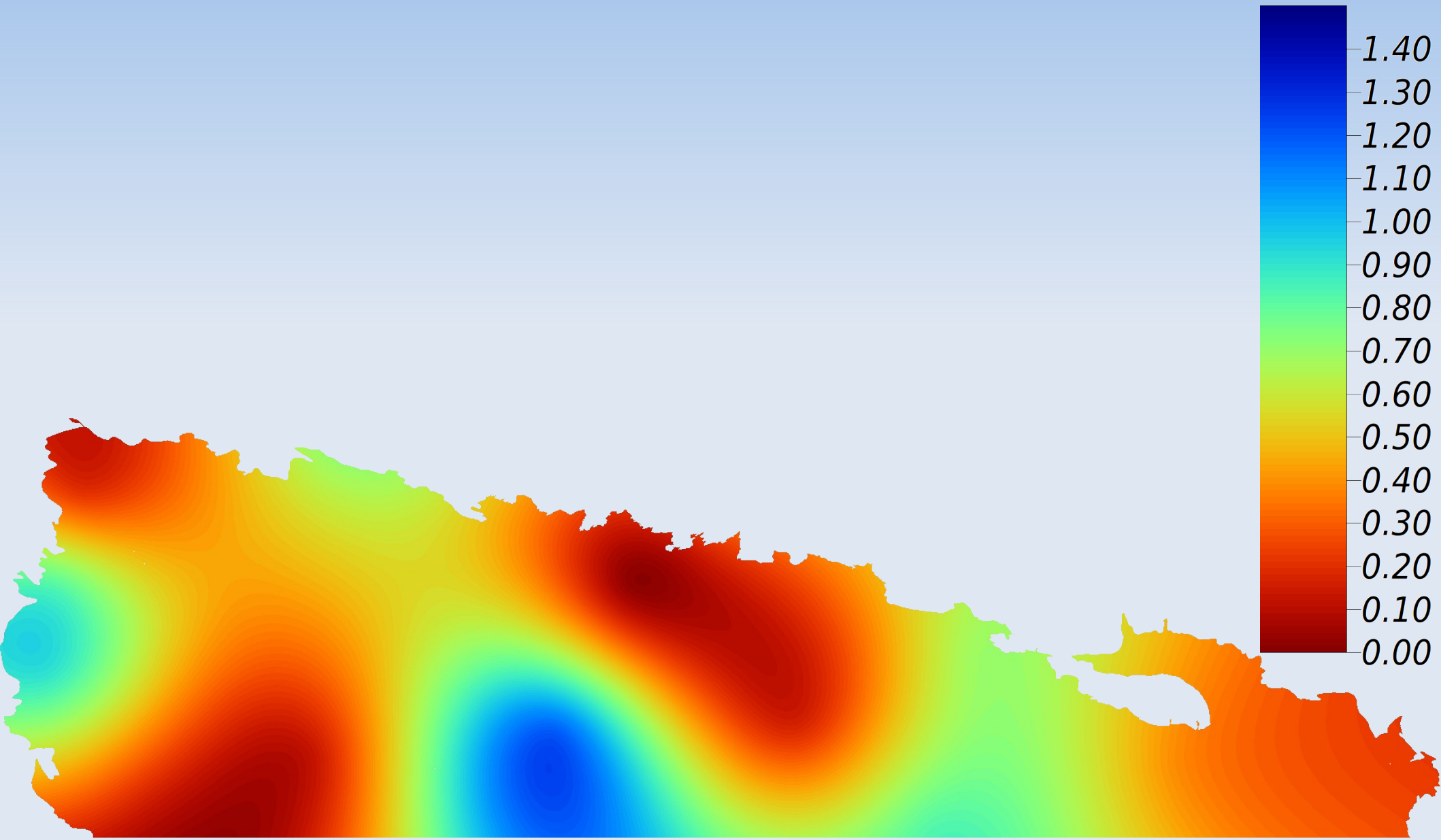
2001 Annual Discharge/Normal



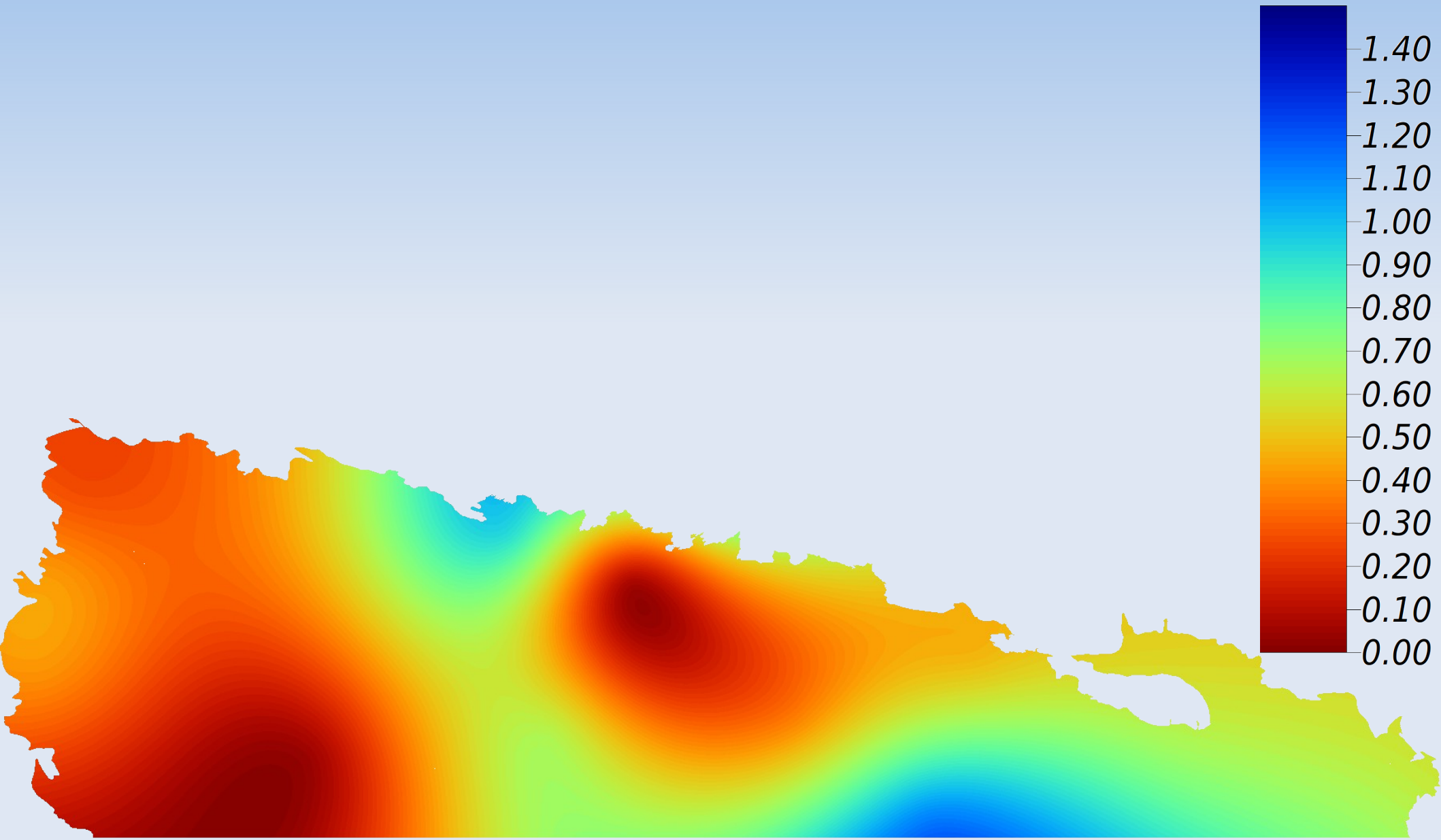
2002 Annual Discharge/Normal



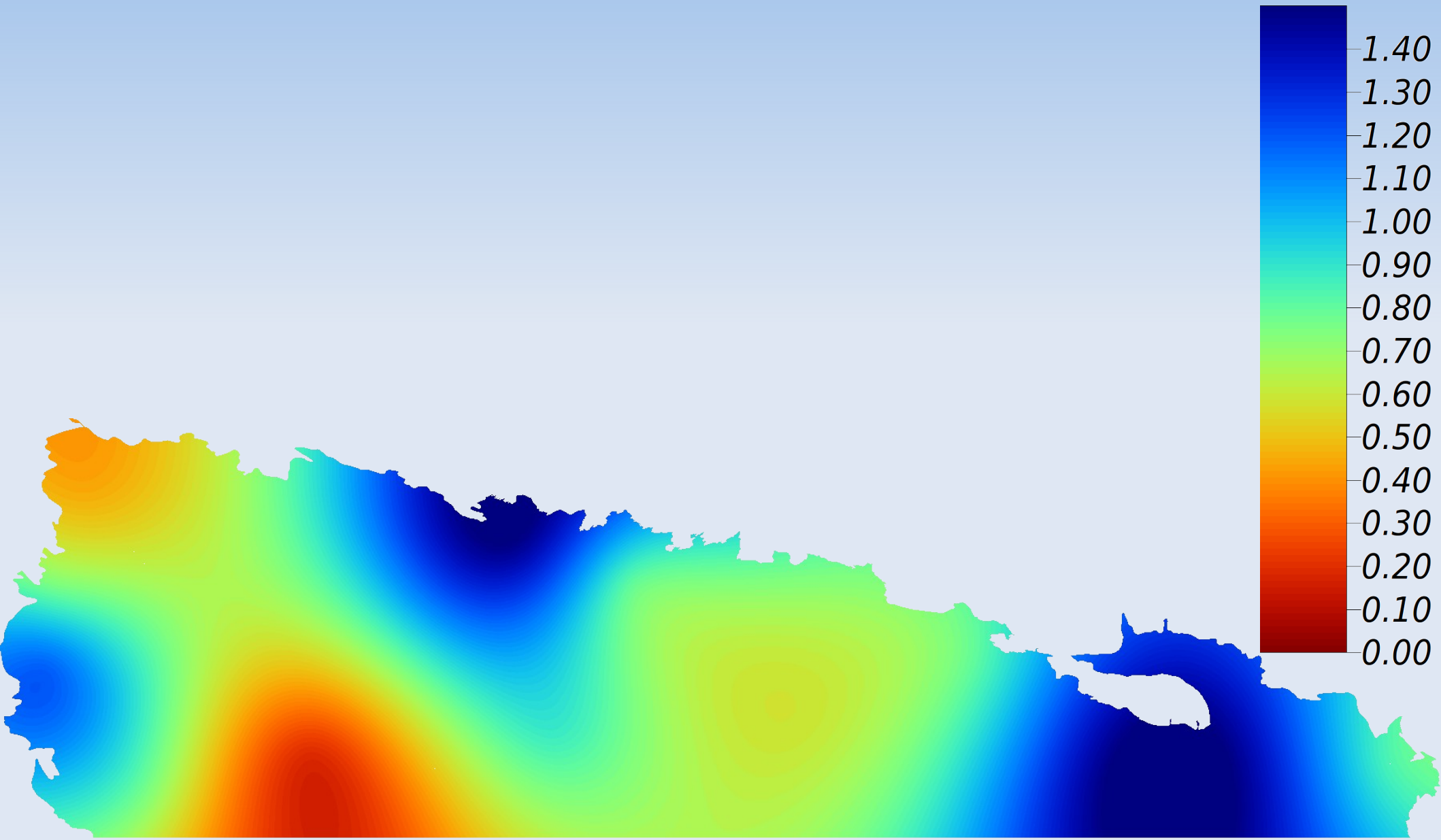
2003 Annual Discharge/Normal



2004 Annual Discharge/Normal



2005 Annual Discharge/Normal



Summary

- Simulations have been run at all 15 locations using the first CRHM model
- Simulation results are preliminary
- The spatial and temporal extents of the hydrological drought can now be visualised
- Second CRHM model has yet to be used

Acknowlegements

- SGI Canada
- DRI
- Data Access Integration
  (http://quebec.ccsn.ca/DAI/) for data

  Apart from CRHM, this research was done entirely with Open Source Software:

  - R - data reduction, statistics
  - Qgis, SAGA - GIS
  - Open Office - presentation