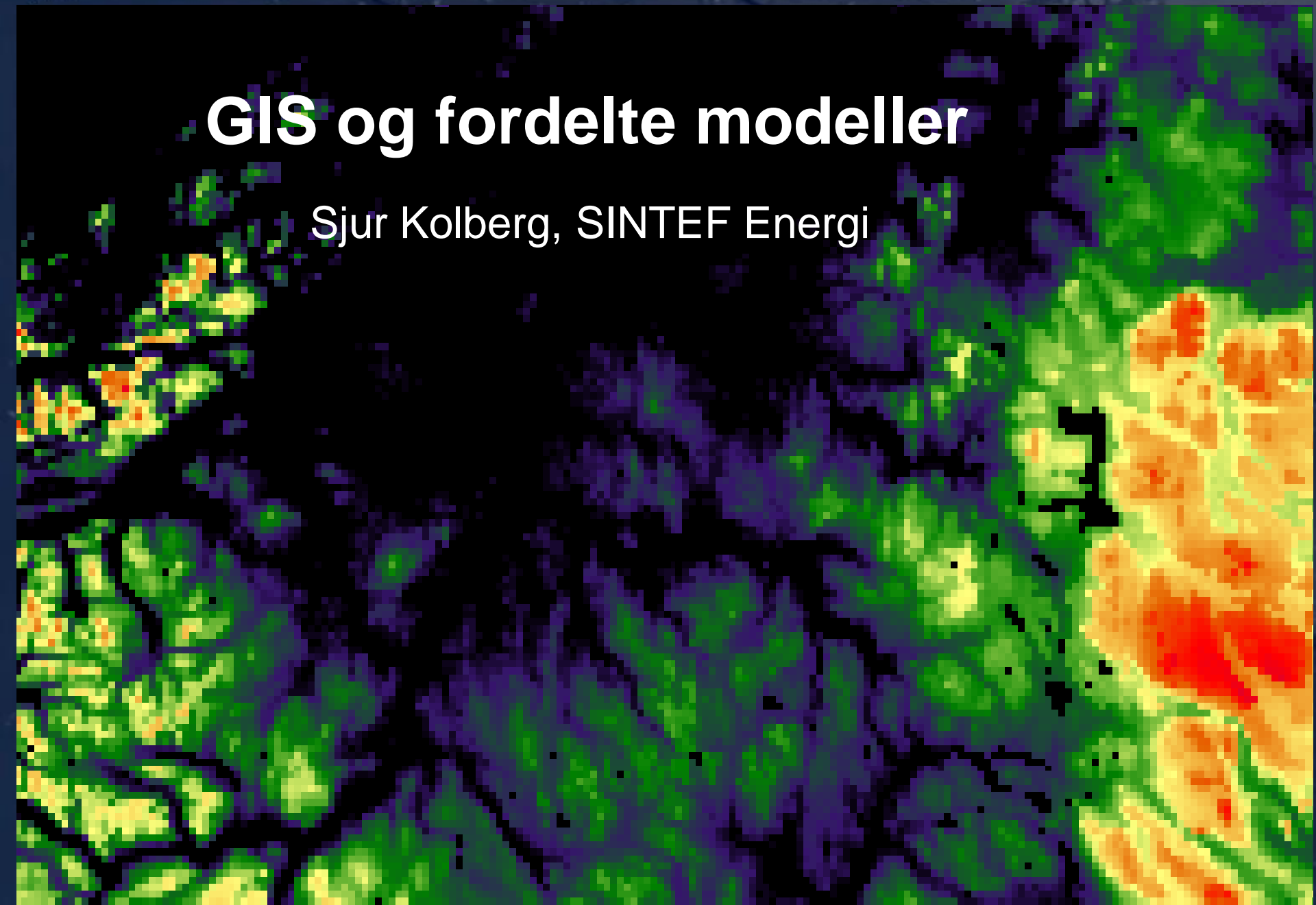


GIS og fordelte modeller

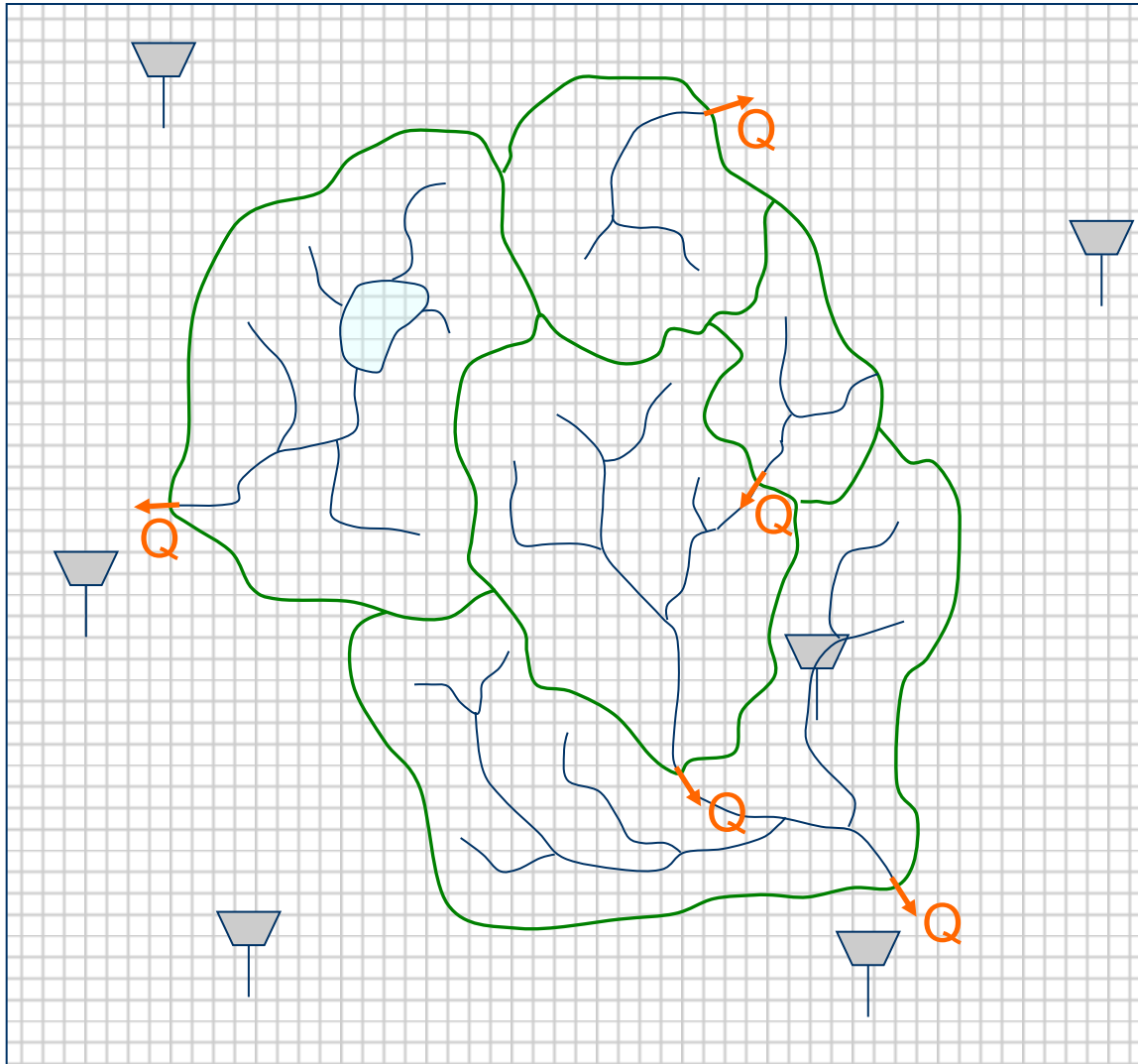
Sjur Kolberg, SINTEF Energi



Distributed hydrological modeling and GIS

- Exploiting the full potential in distributed hydrological modelling more or less requires a supporting GIS
- The core simulation, however, will rarely be performed within the GIS program itself, due to performance issues
- Possible routes for integration:
 - Running the model from the GIS program
 - Calling GIS program functions from the running model
 - Memory or disk file data exchange?
- Preprocessing of model data in the GIS
- Visualisation, analysis and storage of results in the GIS
- Most GIS do not handle the temporal dimension well.

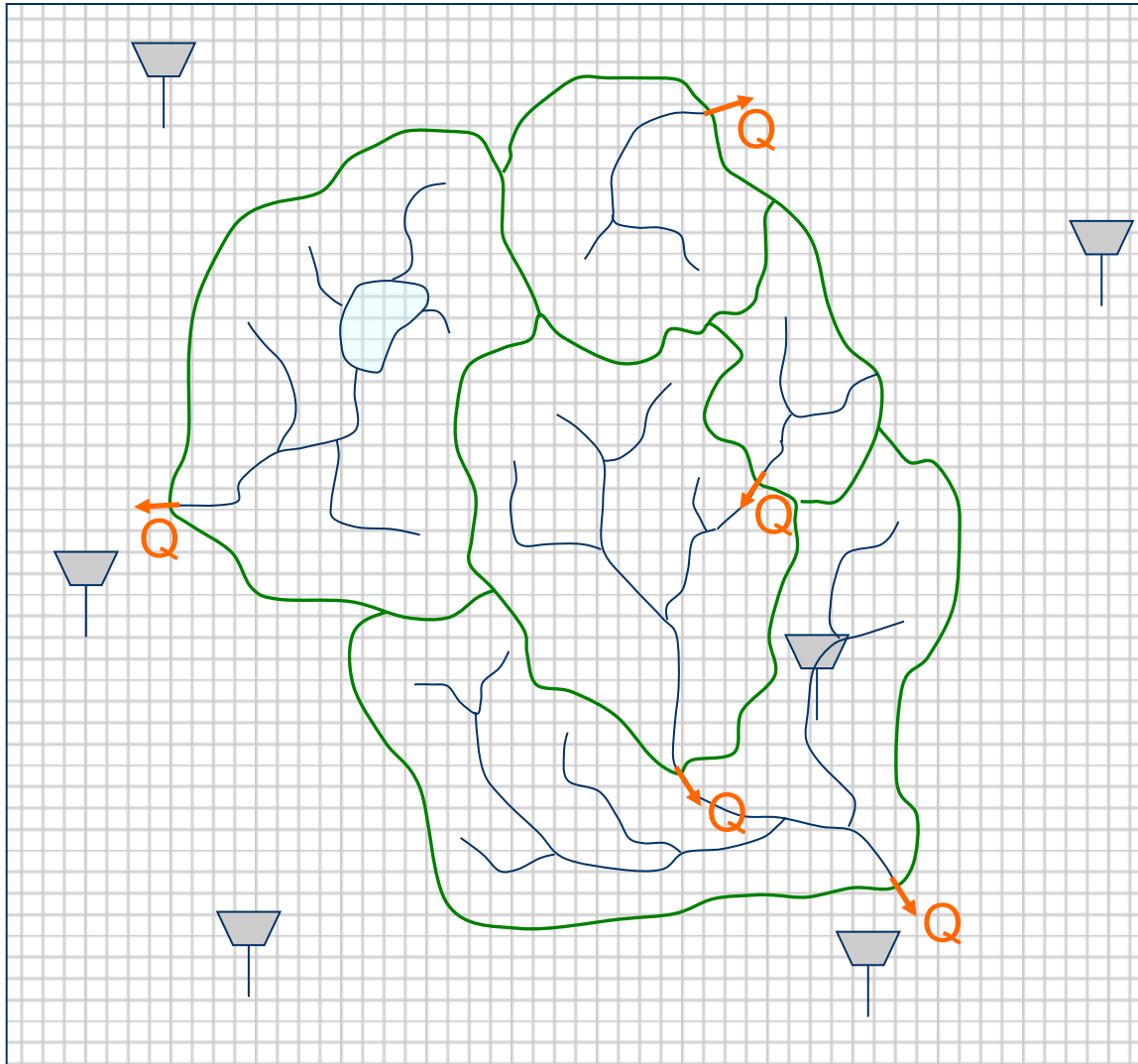
Motivation:



Operational:

- One distributed model over a region replaces many HBV models
- Common setup of input data and calibration
- Simulates ungauged basins, hydropower market regions etc.
- Objective estimation of areal precipitation and other input variables.
- Easy to integrate weather radar, satellite imagery, gridded met. forecasts etc.
- Map visualisation provides a good overview of the hydrological state in the region.

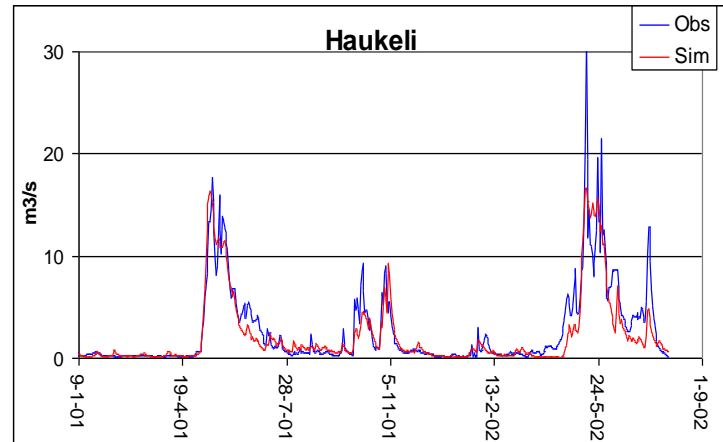
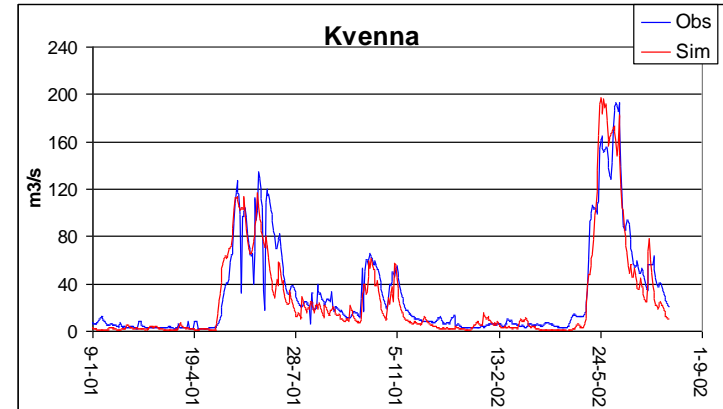
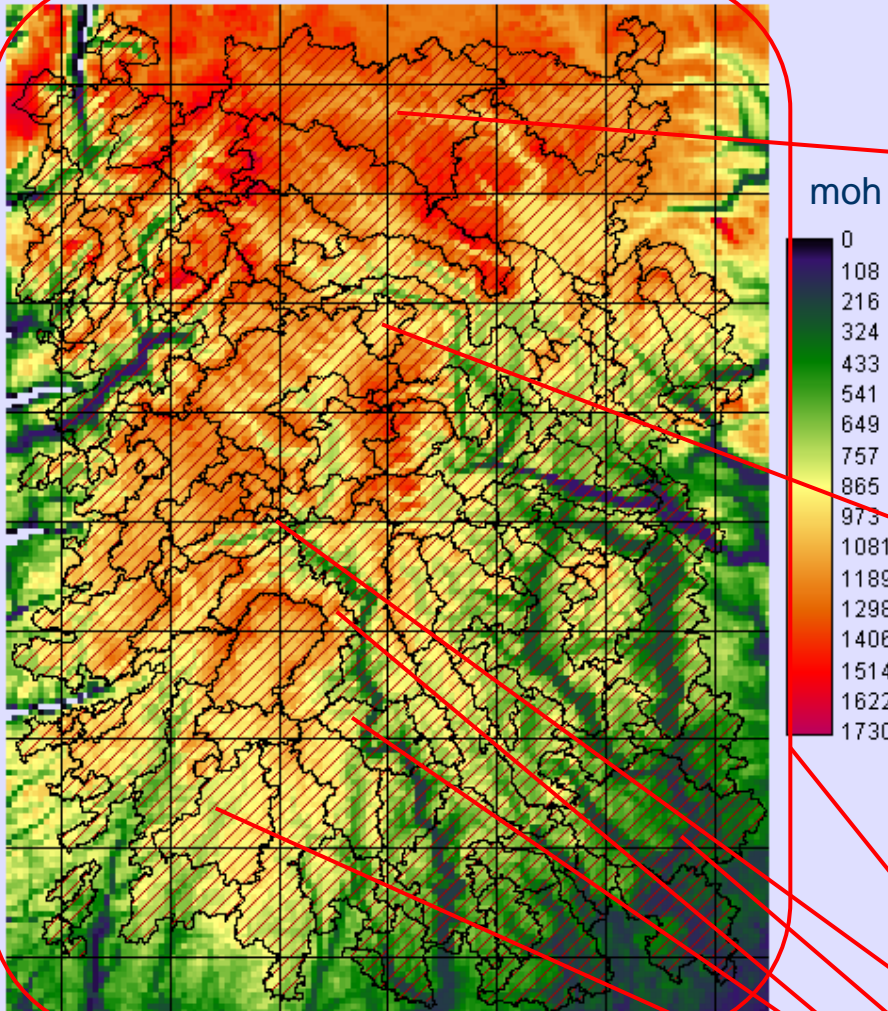
Motivation:



Hydrological:

- Better physical description makes the model more robust towards unusual conditions
- Areal distribution of input data important for large basins near the water divide.
- Spatial distribution of states enables rapid response from parts of the catchment
- Measured information in neighbour catchments can support both calibration and updating

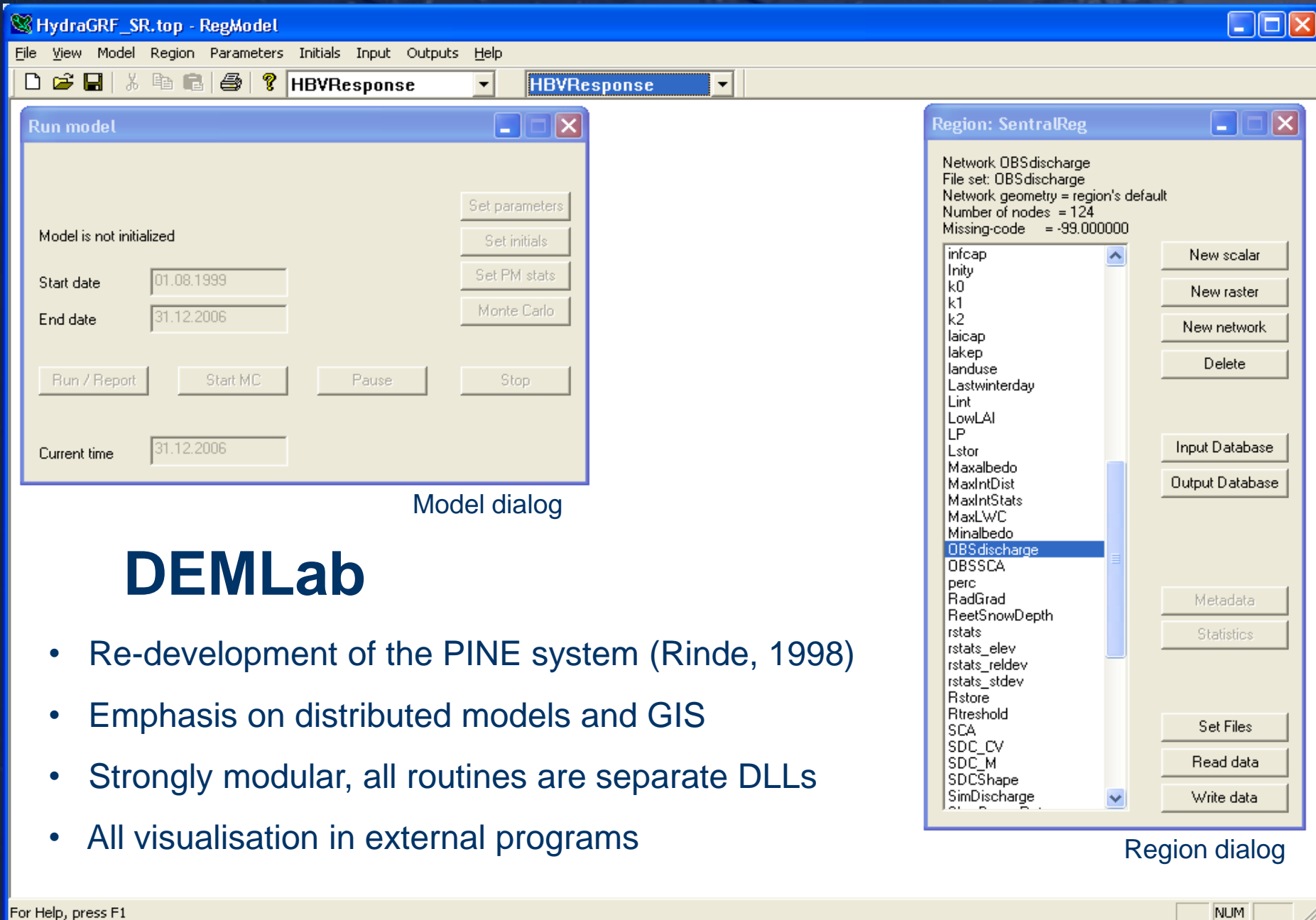
Vilkårlige områder



- Markedsregion
- Bekkeinntak
- Restfelt til punkt med minste vannføring
- Andre umålte felt

Distributed modelling software

- SINTEF Energy Research has been developing a modular software framework for Statkraft since 2002.
- This framework (currently named DEMlab) is in the process of being released as an Open Source project.
- R&D cooperation between Statkraft and other hydropower institutions is already established
- The Open Source approach facilitates easy integration of results achieved in i.e. EBL projects.
- Open Source GIS data library GDAL ensures compatibility with most GIS programs, including both ArcGIS and Open Source GIS tools (GRASS, SAGA, Quantum GIS).



The screenshot shows the HydraGRF software interface. The main window is titled "HydraGRF_SR.top - RegModel". The menu bar includes File, View, Model, Region, Parameters, Initials, Input, Outputs, and Help. The toolbar contains icons for file operations and a dropdown menu set to "HBVResponse".

The "Run model" dialog box is open, showing the following fields and buttons:

- Model is not initialized
- Start date: 01.08.1999
- End date: 31.12.2006
- Current time: 31.12.2006
- Buttons: Run / Report, Start MC, Pause, Stop, Set parameters, Set initials, Set PM stats, Monte Carlo.

The "Region: SentralReg" dialog box is also open, showing the following information:

- Network: OBSdischarge
- File set: OBSdischarge
- Network geometry = region's default
- Number of nodes = 124
- Missing-code = -99.000000
- Buttons: New scalar, New raster, New network, Delete, Input Database, Output Database, Metadata, Statistics, Set Files, Read data, Write data.
- List of parameters: infcap, Inity, k0, k1, k2, laicap, lakep, landuse, Lastwinterday, Lint, LowLAI, LP, Lstor, Maxalbedo, MaxIntDist, MaxIntStats, MaxLWC, Minalbedo, **OBSdischarge**, OBSSCA, perc, RadGrad, ReetSnowDepth, rstats, rstats_elev, rstats_relddev, rstats_stdev, Rstore, Rthreshold, SCA, SDC_CV, SDC_M, SDCshape, SimDischarge.

Model dialog

Region dialog

DEMLab

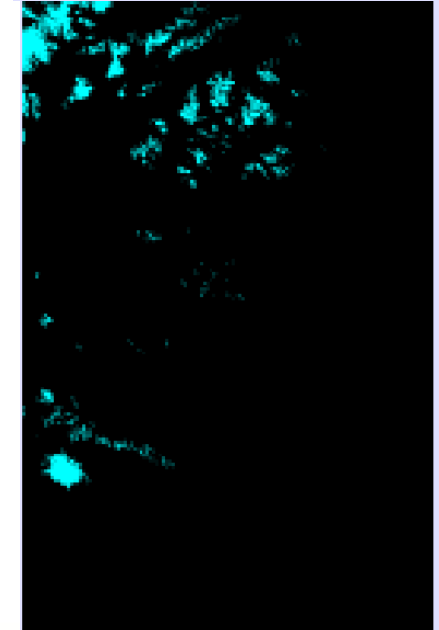
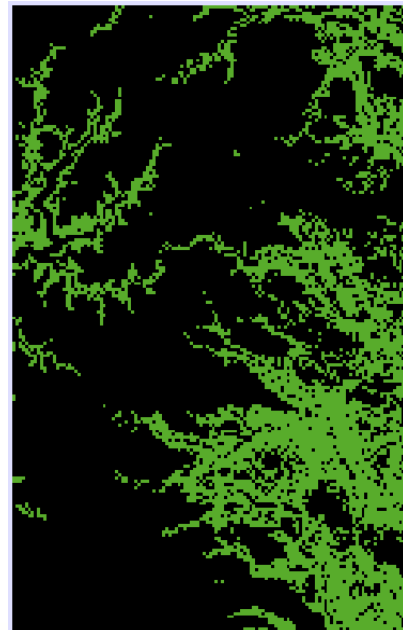
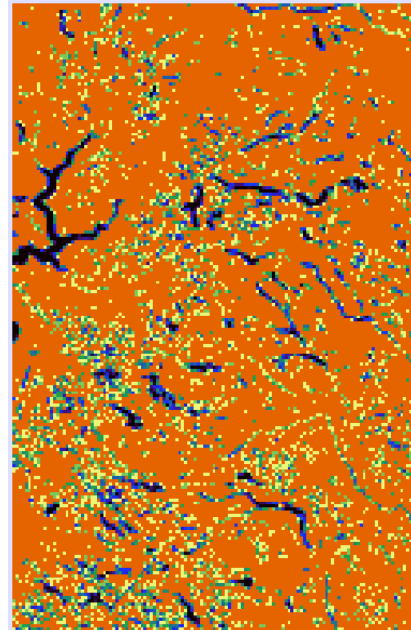
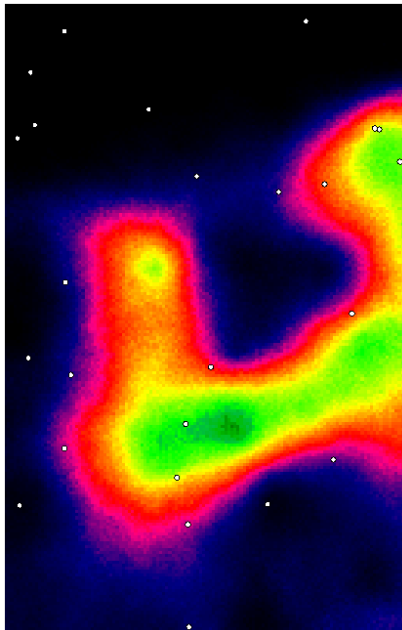
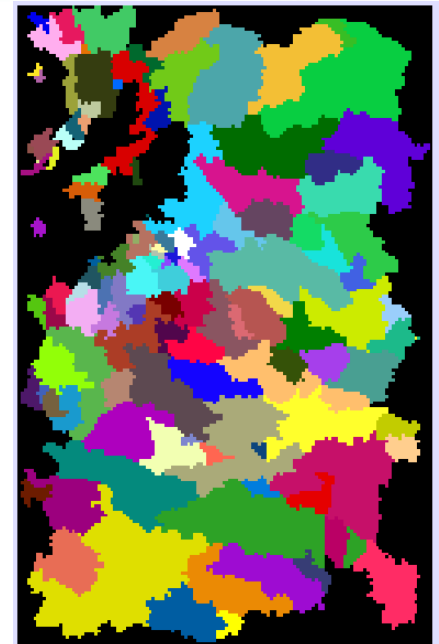
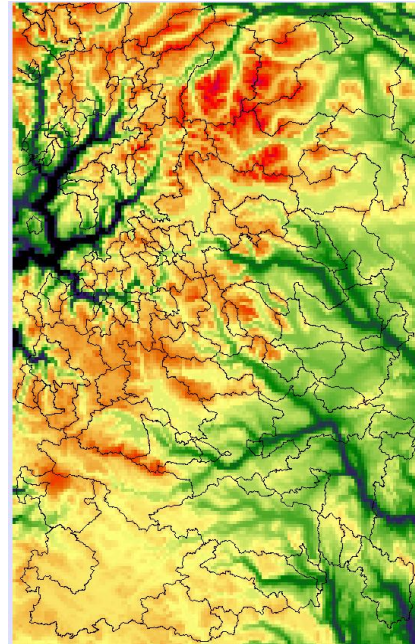
- Re-development of the PINE system (Rinde, 1998)
- Emphasis on distributed models and GIS
- Strongly modular, all routines are separate DLLs
- All visualisation in external programs

GIS and variable types in distributed models

- Model variables have GIS types: Raster, point network, scalars
- Different roles in the model:
 - Static background maps (usually rasters)
 - Parameters (Adjustable information; usually scalars)
 - Input variables (time series of point or raster data)
 - States (Usually rasters, need initialisation)
 - Responses (Rasters or discrete point time series).

GIS based model setup:

- Elevation map (DEM)
- Subcatchment division
- Measurement gauge map
- Lake map
- Forest map
- Glacier percentage map



bakgrunn

rammeverket DEMLab

hydrologisk modell

regional kalibrering

resultat

muligheter videre⁹

Automatic calibration

Monte Carlo Parameter Estimation Setup

Distribution: Value: Variance: Min: Max:

TempGrad (Current value: -0.9)

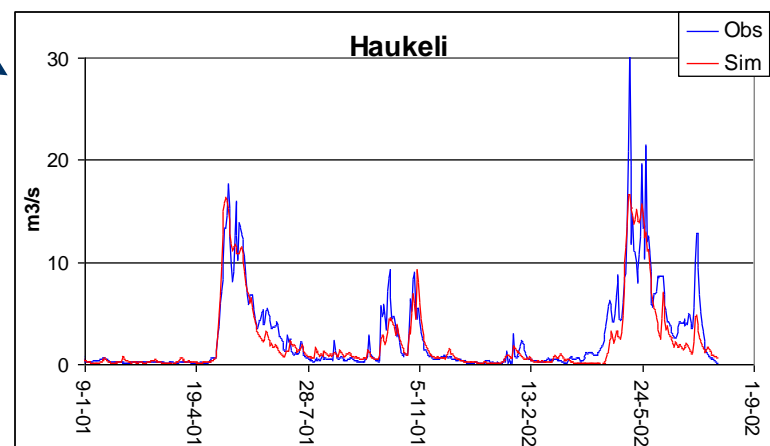
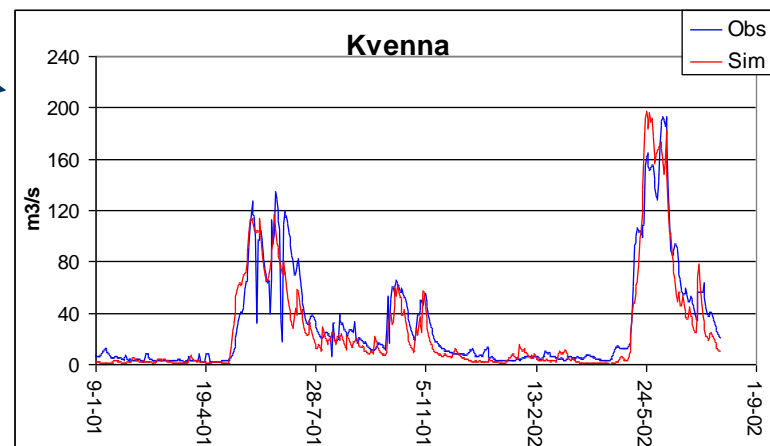
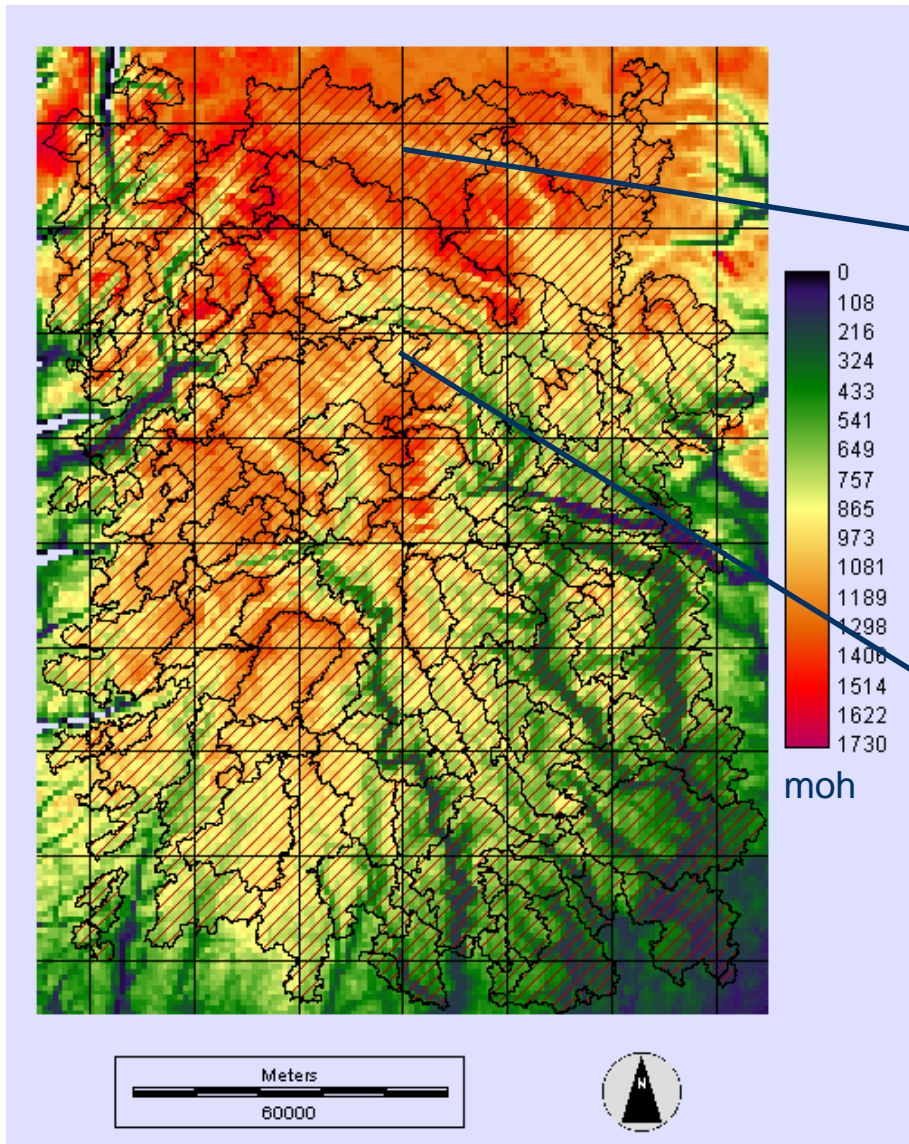
Parameter	Routine	Minimum	Maximum	Distribution
fieldcap	HydraSoil	0	3.40282E+0...	Uniform(120,300)
infcap	HydraSoil	0	3.40282E+0...	100
etmp	HydraEP	-3.40282E+...	3.40282E+0...	Uniform(0.05,0.2)
consthum	Consthum	-3.40282E+...	3.40282E+0...	80
BETA	HydraSoil	-3.40282E+...	3.40282E+0...	Uniform(1,2)
TempGrad	IDWtemp	-3.40282E+...	3.40282E+0...	Uniform(-0.9,-0.5)
tvsum	HydraEP	0	3.40282E+0...	Uniform(50,200)
Constwind	Constwind	-3.40282E+...	3.40282E+0...	1
ReetSnowDepth	GamSnow	0	3.40282E+0...	10
TX	GamSnow	-3.40282E+...	3.40282E+0...	Uniform(-1,3)
Rtreshold	HBVRresponse	-3.40282E+...	3.40282E+0...	20
LP	HydraSoil	-3.40282E+...	3.40282E+0...	0.9
RadGrad	Idwrad	-3.40282E+...	3.40282E+0...	0
Windconst	GamSnow	-3.40282E+...	3.40282E+0...	Uniform(0,2)
FastDecayRate	GamSnow	0	3.40282E+0...	Uniform(2,5,5)
MaxIntDist	Idwrad;IDWtemp	0	3.40282E+0...	300000
esnw	HydraEP	-3.40282E+...	3.40282E+0...	0.1
epcorr	HydraEP	-3.40282E+...	3.40282E+0...	Uniform(0.5,2)
MaxLWC	GamSnow	0	1	0.1
Maxalbedo	GamSnow	0	1	Uniform(0.85,0.95)
ewnd	HydraEP	-3.40282E+...	3.40282E+0...	Uniform(0.3,0.7)
perc	HBVRresponse	-3.40282E+...	3.40282E+0...	Uniform(0.1,0.3)
k0	HBVRresponse	-3.40282E+...	3.40282E+0...	Uniform(0.02,0.06)
MaxIntState	Idwrad;IDWtemp	0	3.40282E+0...	25

MC method

- Nelder-Mead
Global, simplex procedure.
- SCE-UA
Global shuffled complex evolution. Slow and robust for difficult cases.
- Restricted Newton
Gradient search with parameter bounds.
- Marquardt-Levenberg
Multi-surface gradient search using the Jacobian matrix (PEST algorithm)
- Pure MC (GLUE)
Random drawing from specified distributions

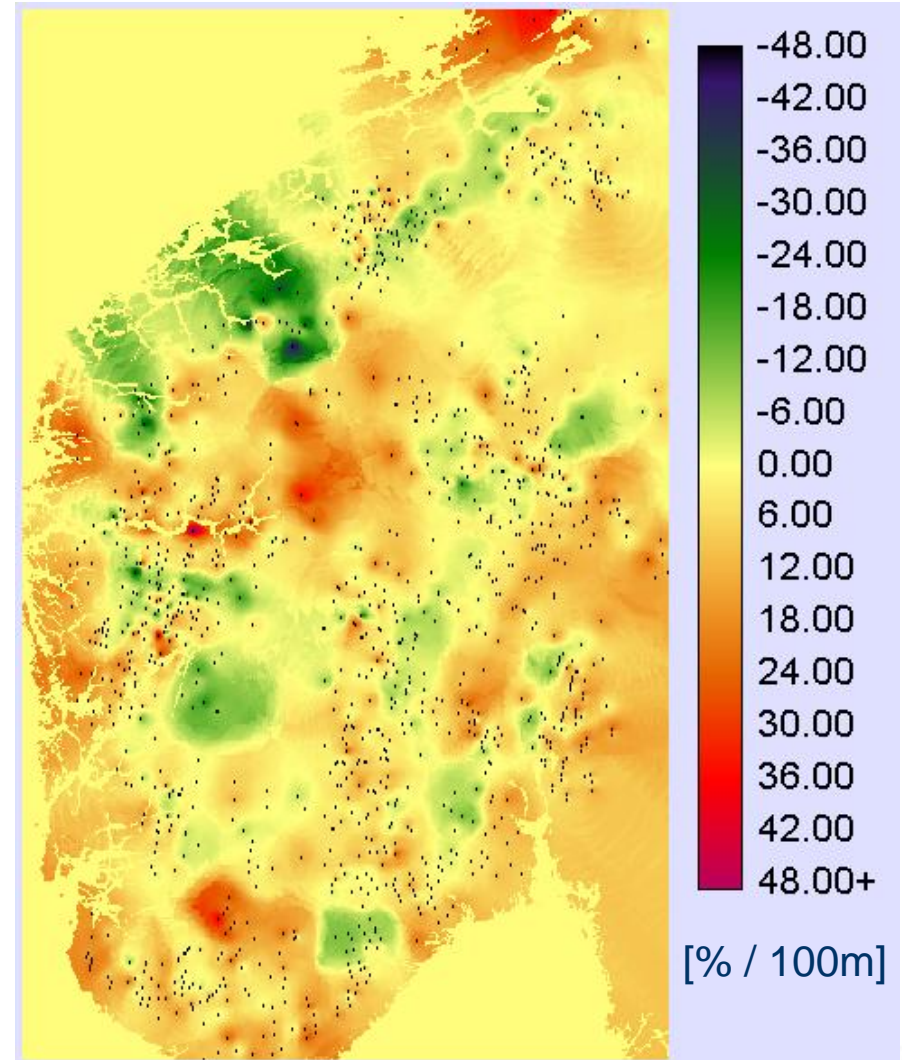
Set Seed # MC runs: Store output

Regional simulation and calibration

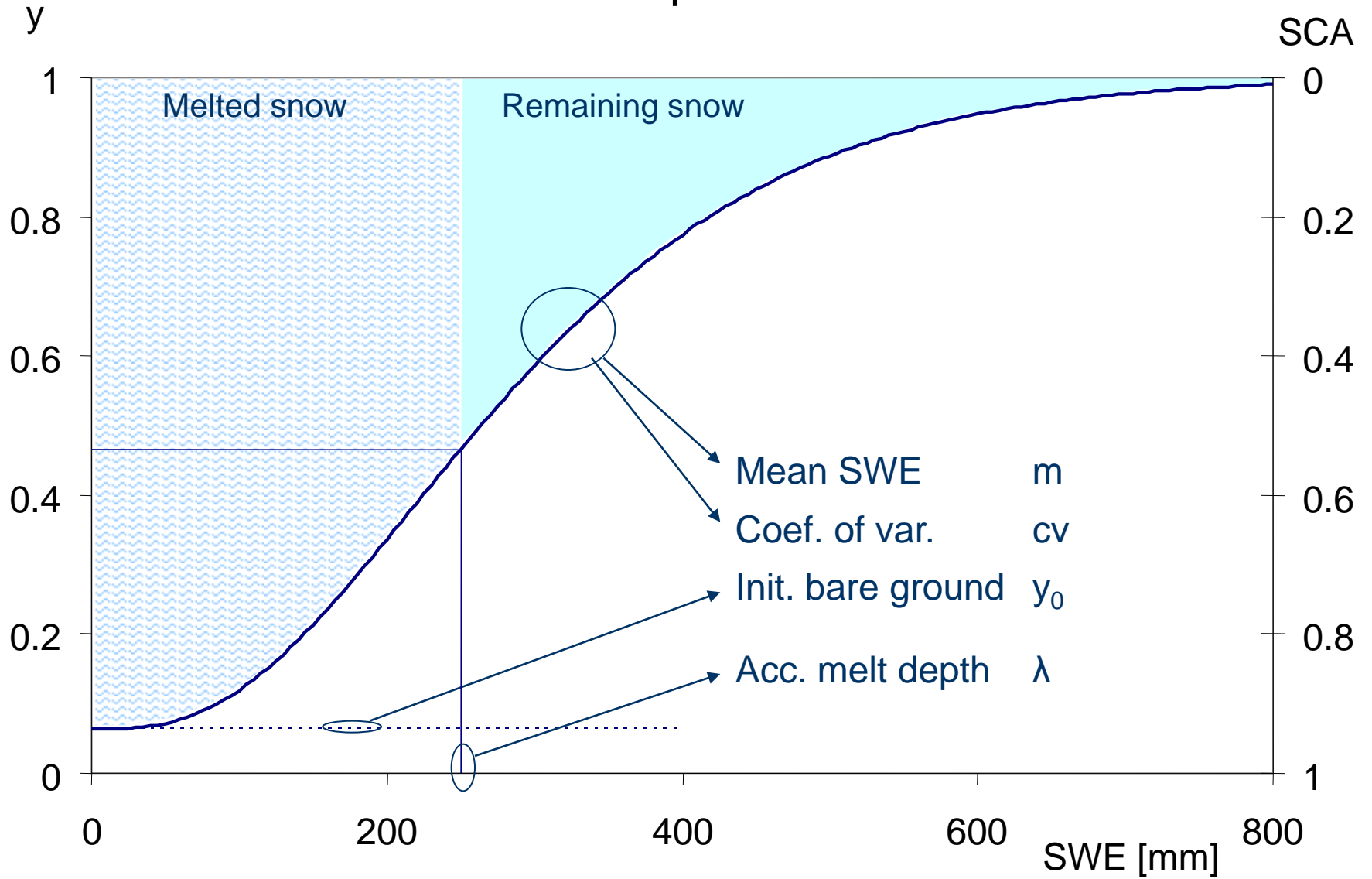


Regional pattern in the elevation dependency of precipitation?

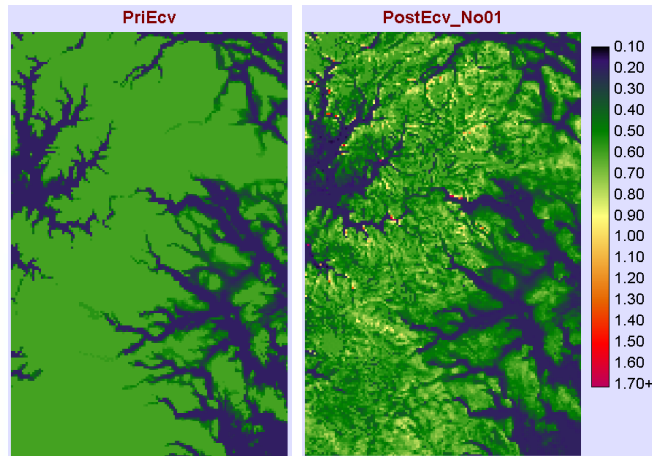
- Long-term all-region average precipitation lapse rate: 3.6 +/- 0.29 [% / 100m]
- A considerable part of the variation follows regional patterns
- Some places show strong variability over short distances
- Some extreme values may depend on a single or a few stations.



The Snow Depletion Curve

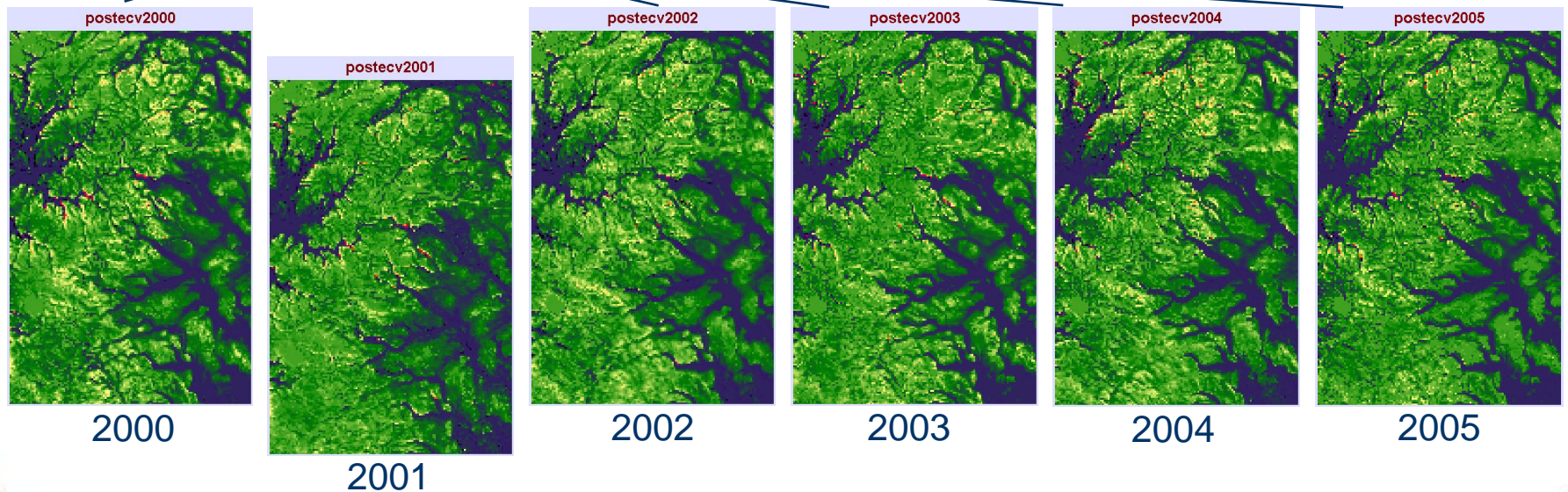


Results: Sub-grid heterogeneity CV

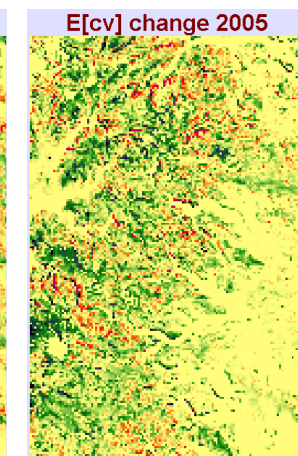
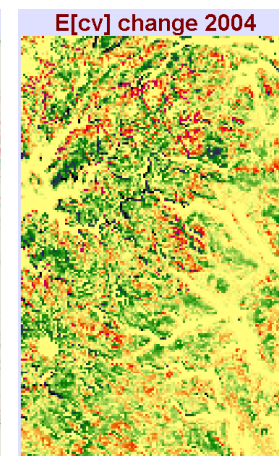
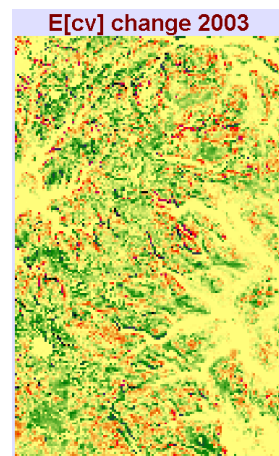
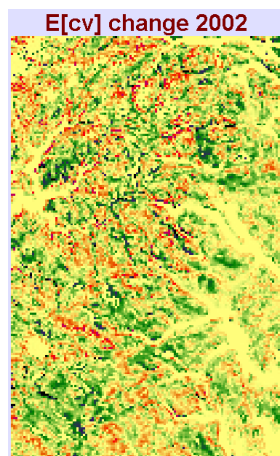
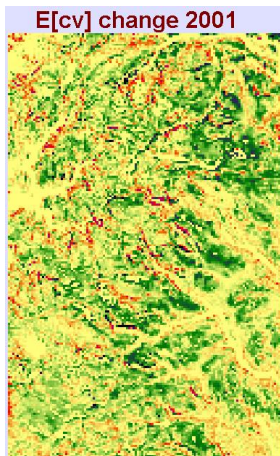
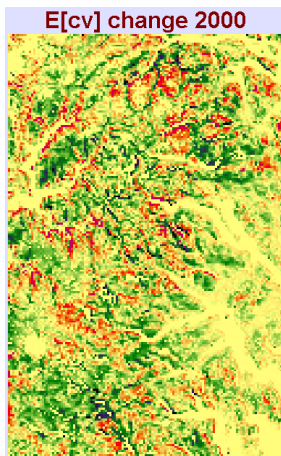
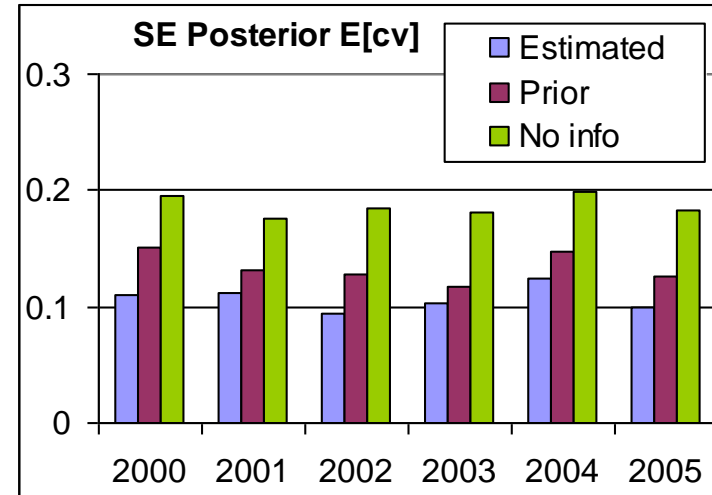
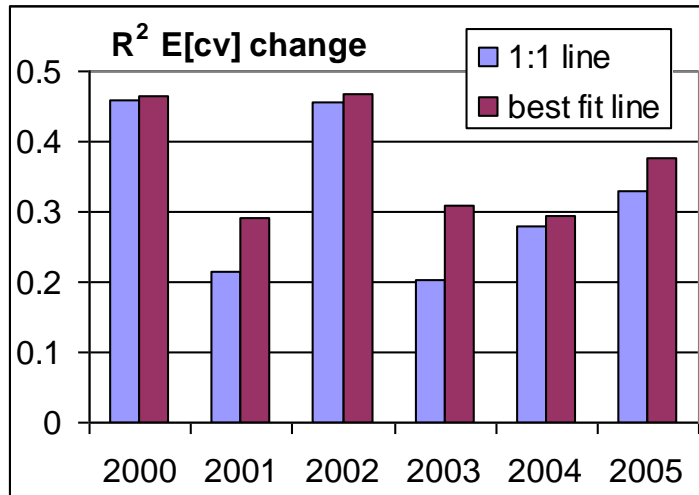


- Prior expectation depending on forest
- Each year a posterior expectation
- Average to estimate a calibrated map
- Evaluate using the left-out year

Prior → Average ←←←←←



Cross-validation results, CV



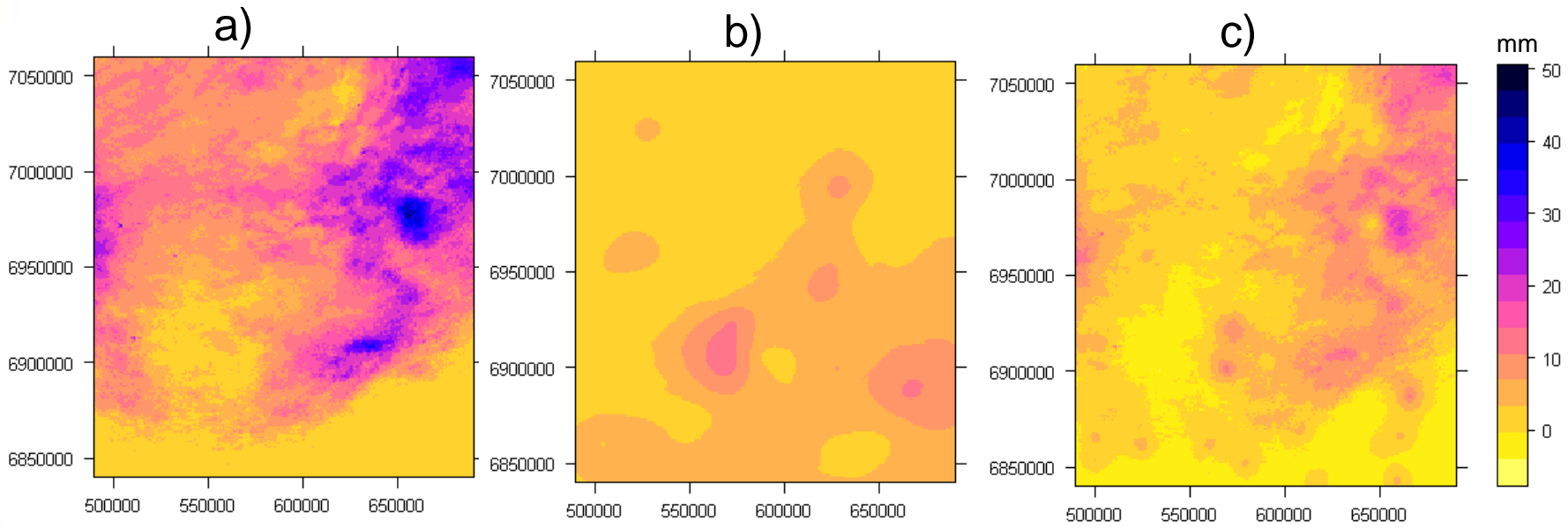
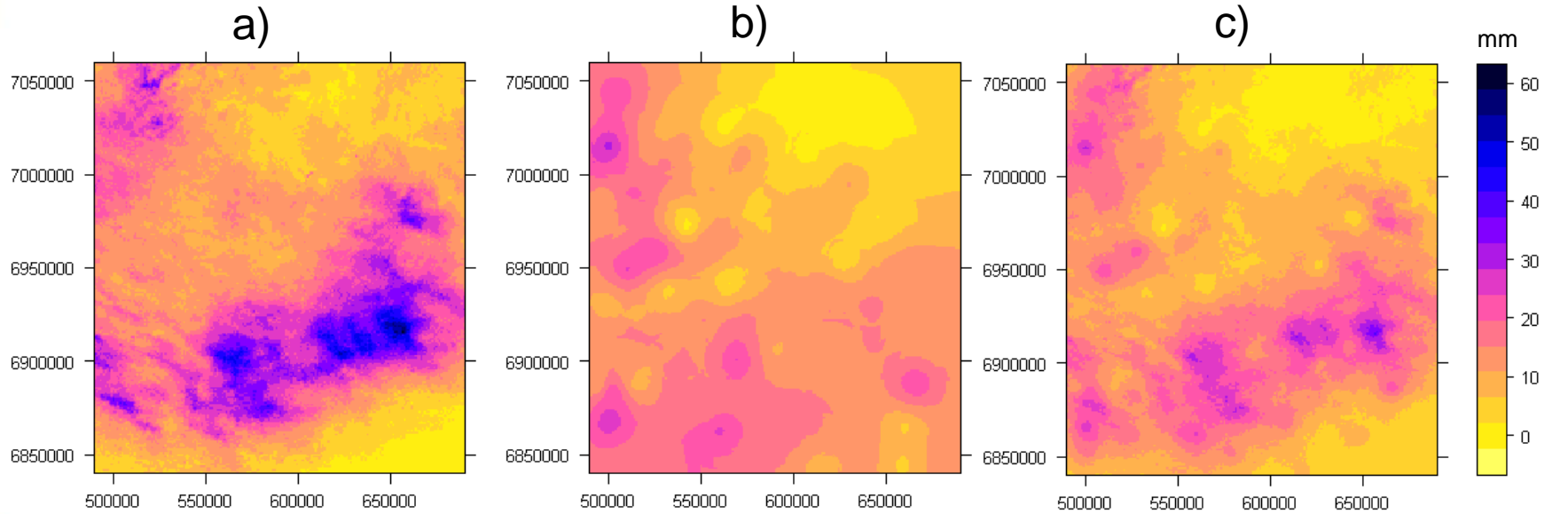


Uncertainty in point precipitation data

Correction	Wind hour	Wind day	Exp kl. 1	Exp kl. 2	Exp kl. 3	Exp kl. 4	Exp kl. 5
Summer	0.06	0.03	0.05	0.07	0.09	0.12	0.18
Winter	0.08	0.03	0.09	0.23	0.32	0.40	0.51

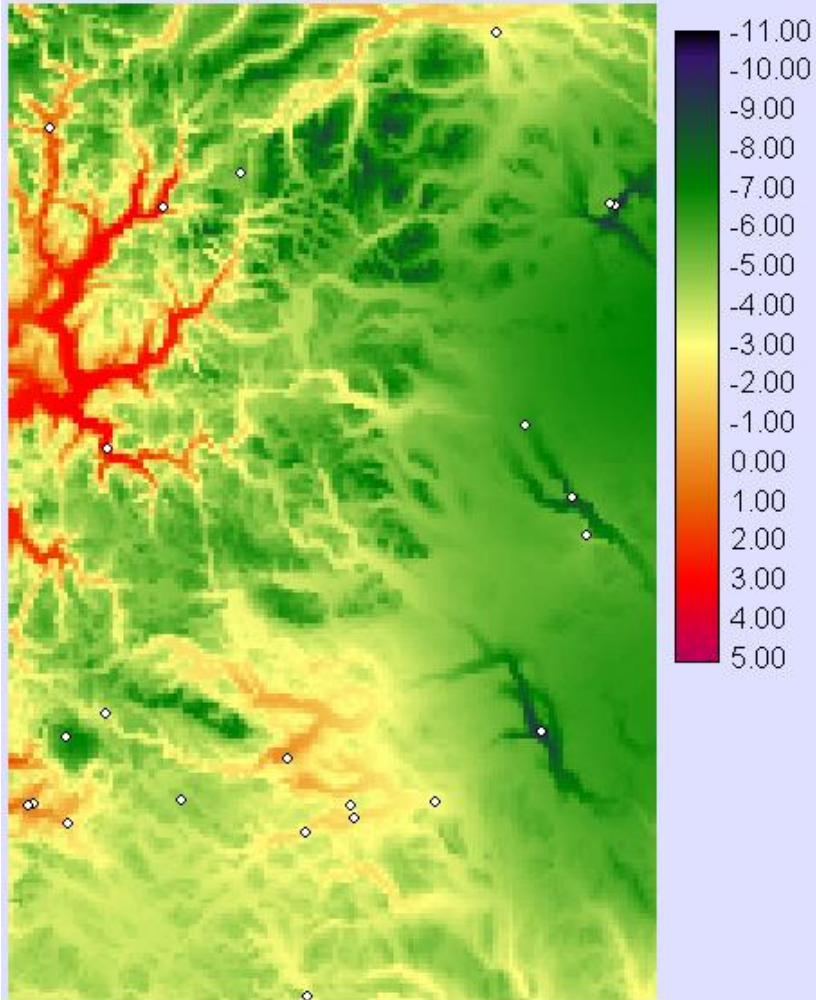
State of weather radar project

- Started summer 2009
- Weather radar data provides promising results
- A method for combining radar and point measurements has been demonstrated for days with rain everywhere. Further development assesses:
 - A better radar error model,
 - Temporal covariance for hourly values
 - Situations with dry subregions
 - Simulation rather than interpolation to estimate uncertainty
- Radar information is being assimilated in local weather models to improve short-term forecasts (met.no)
- Wind information can also be extracted

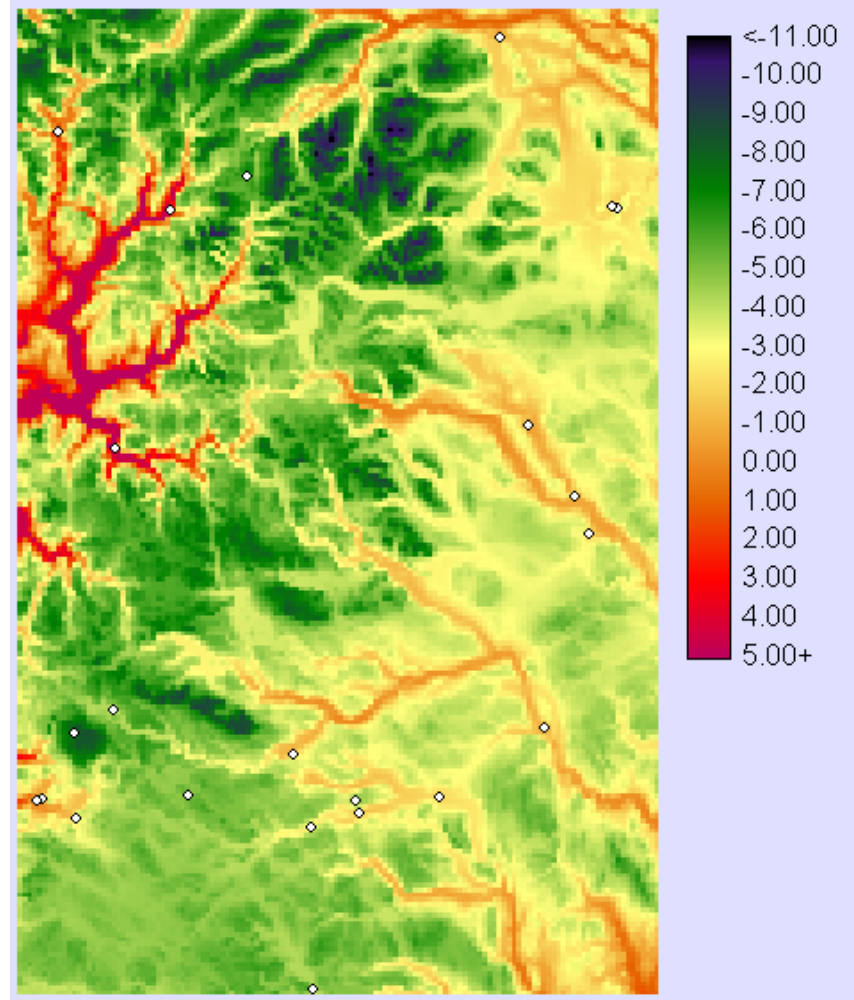


Temperature interpolation

Temp 2 jan 2000



Temp 3 jan 2000



Conclusions

- Distributed models are implemented outside GIS programs
- Due to a widely used GIS data type library, there is no reason to tie the model program to a specific GIS program
- GIS useful in almost all aspects of distributed modeling
- Current R&D in distributed modelling focuses on a regional approach, not the single catchment.
- Distributed hydrological modelling in early operationalisation phase.
- Open Source development encourages participation from many different users and contributors

Takk for oppmerksomheten