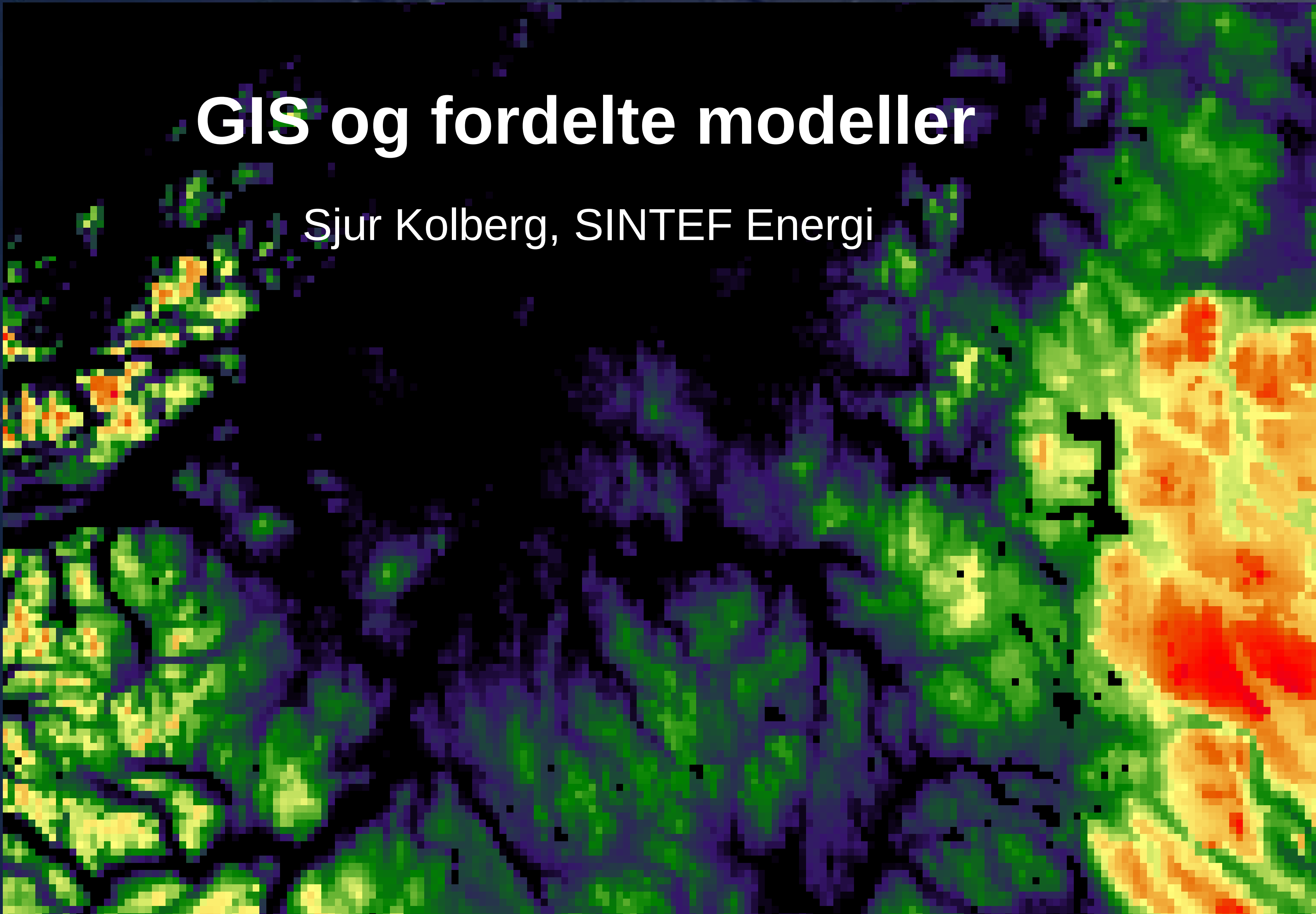
GIS og fordelte modeller

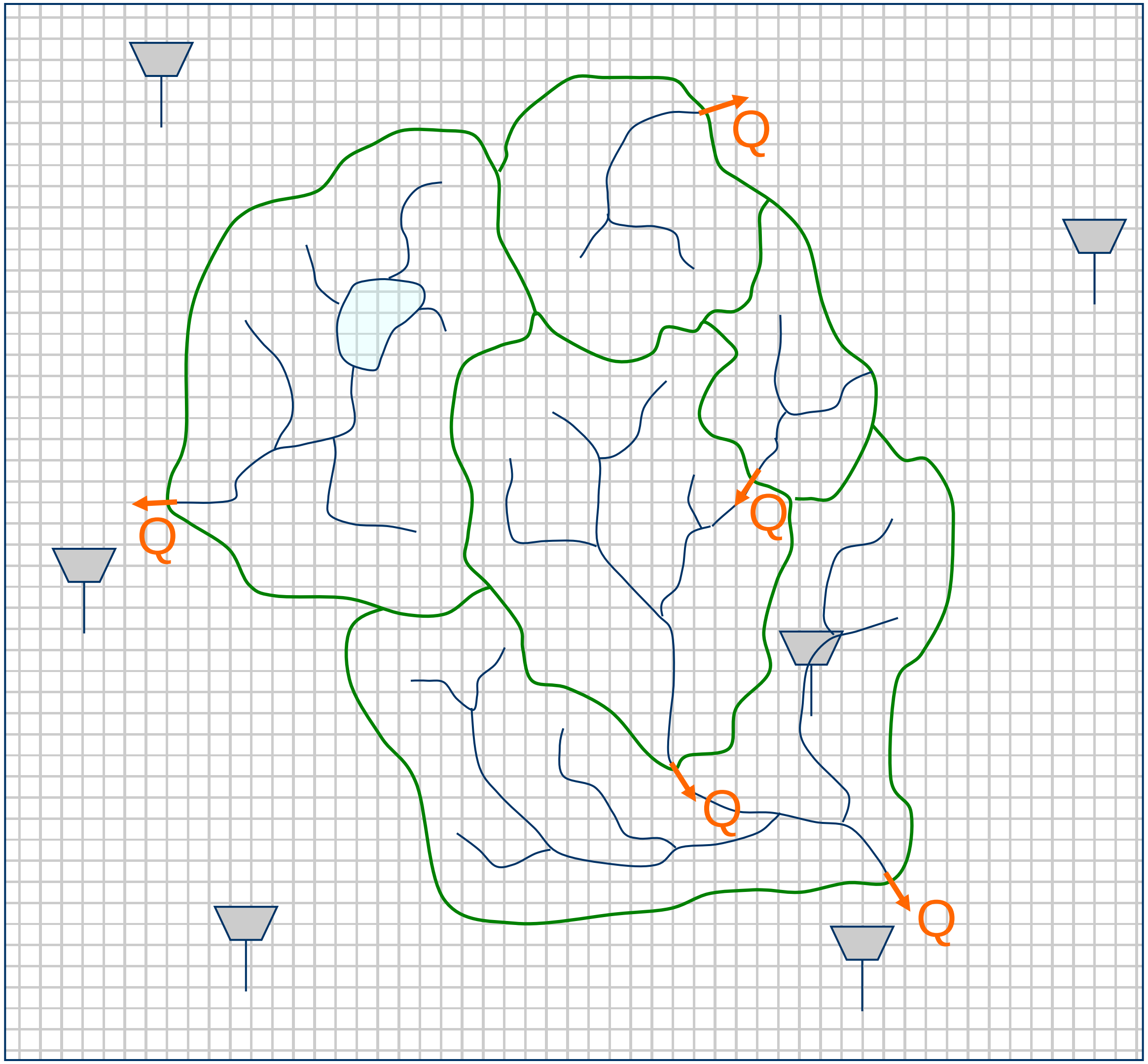
Sjur Kolberg, SINTEF Energi



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?
- Preprosessing of model data in the GIS
- Visualisation, analysis and storage of results in the GIS
- Most GIS do not handle the temporal dimension well.

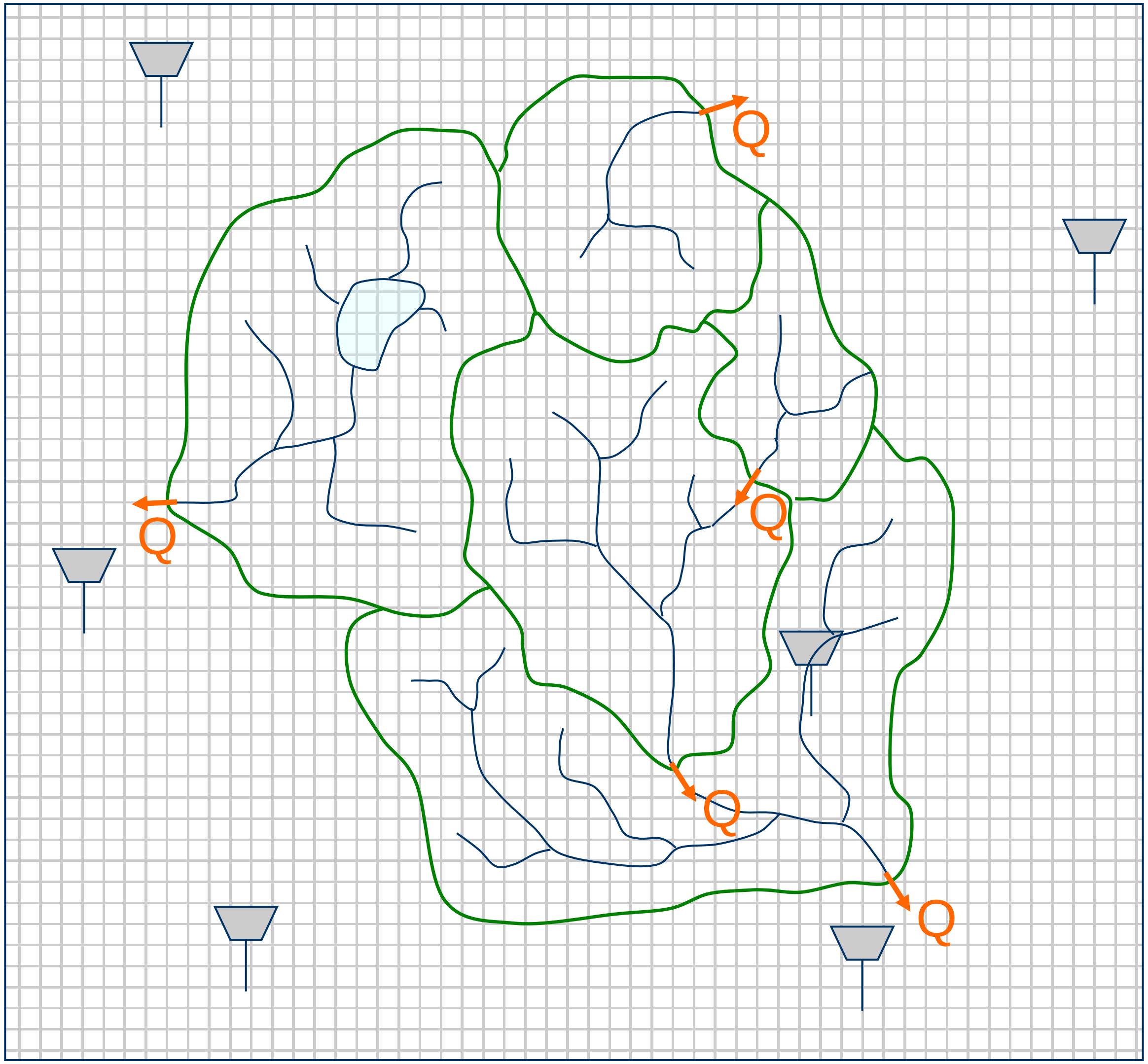
Motivation:



Operational:

- One distributed model over a region replaces many HBV models
- Common setup of input data and calibration
- Simulates ungauged basins, hydropower market regiones 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.

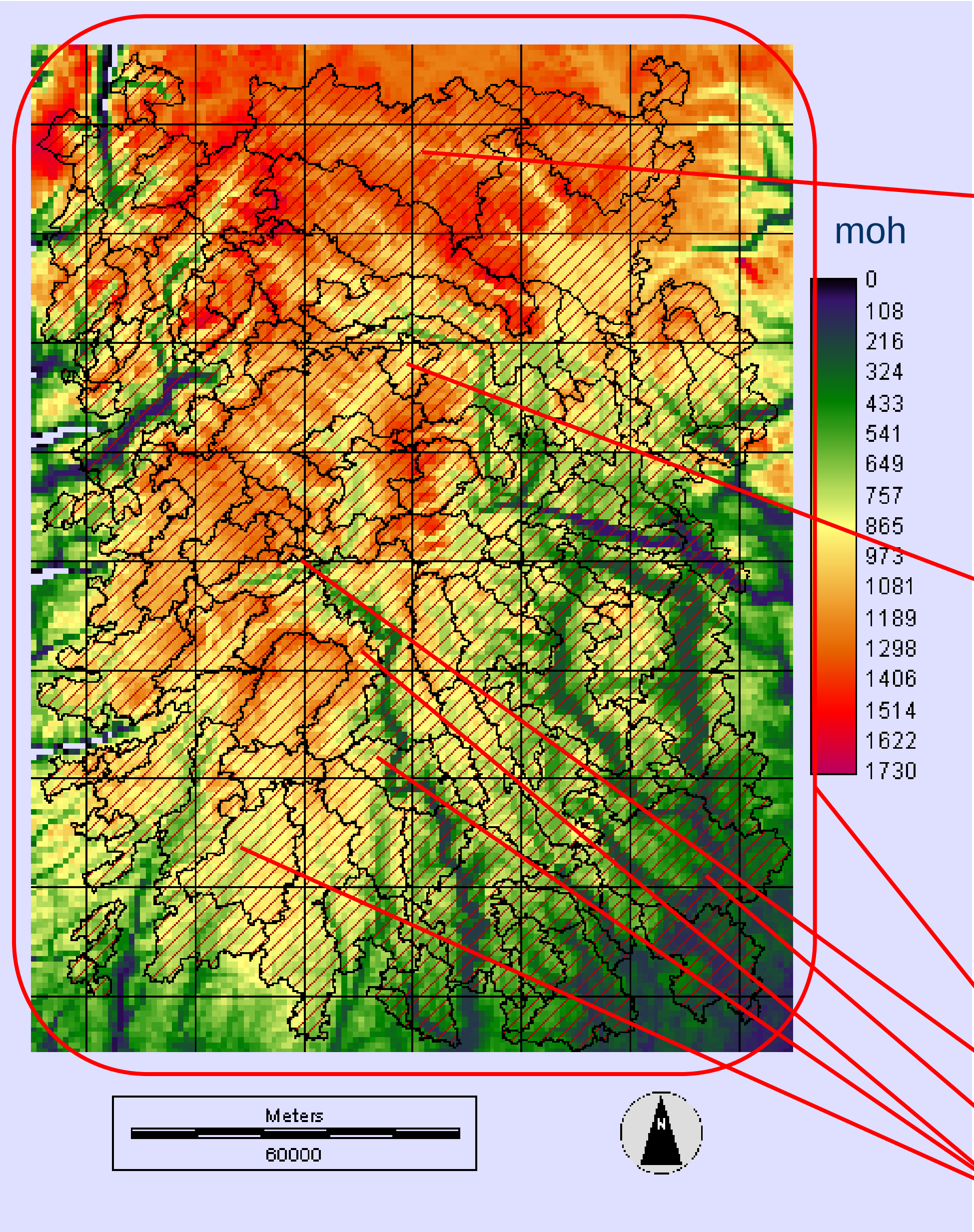
Motivation:

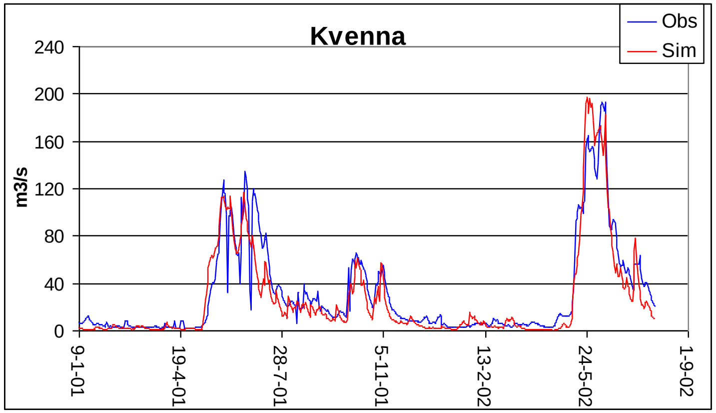


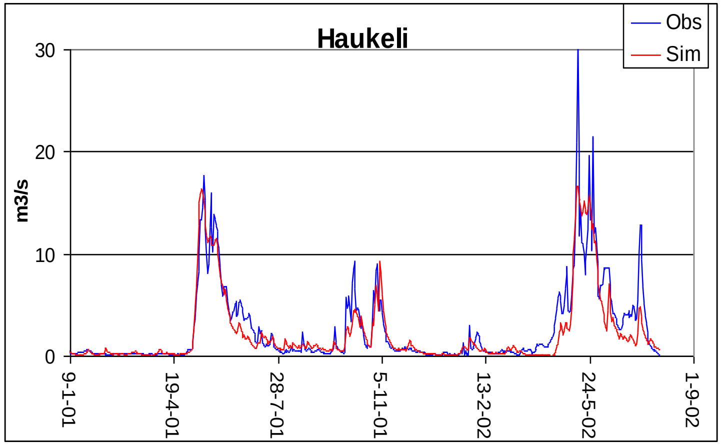
Hydrological:

- 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



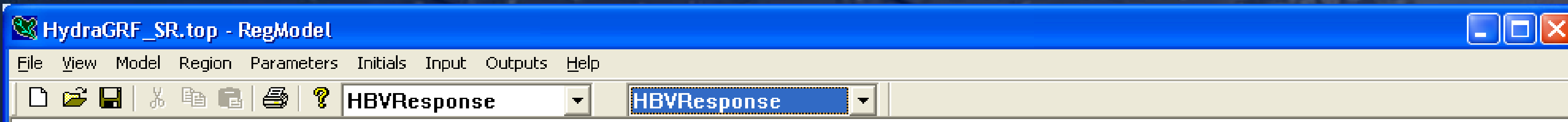


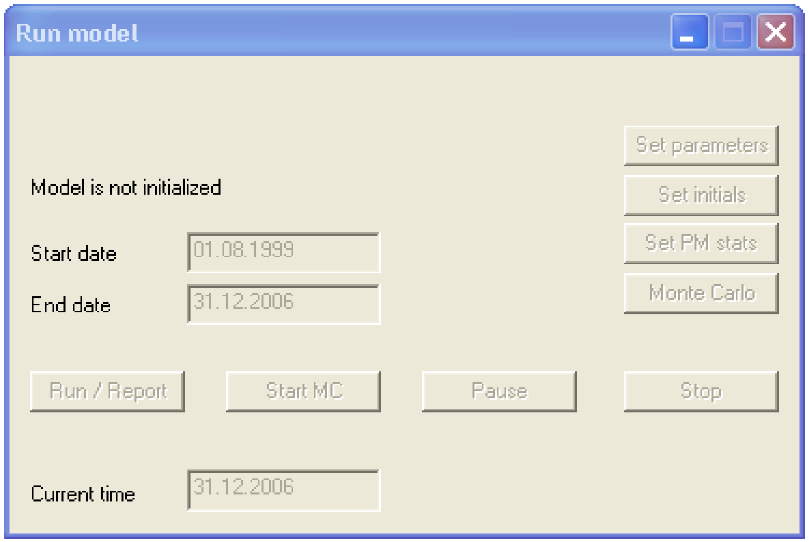


- Markedsregion
- Bekkeinntak
- Restfelt til punkt med minstevannføring
- Andre umålte felt

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).

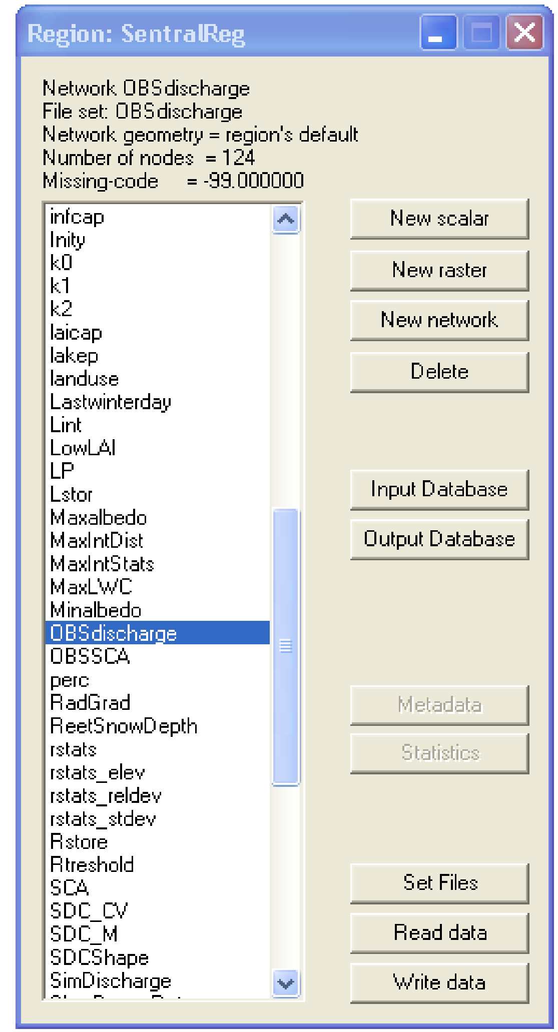




Model dialog

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



Region dialog

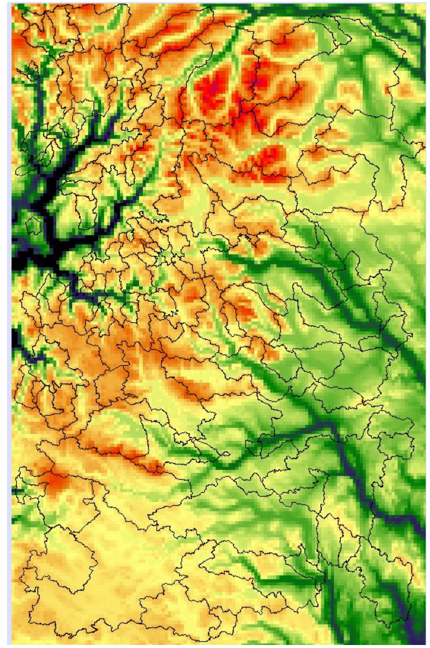
For Help, press F1

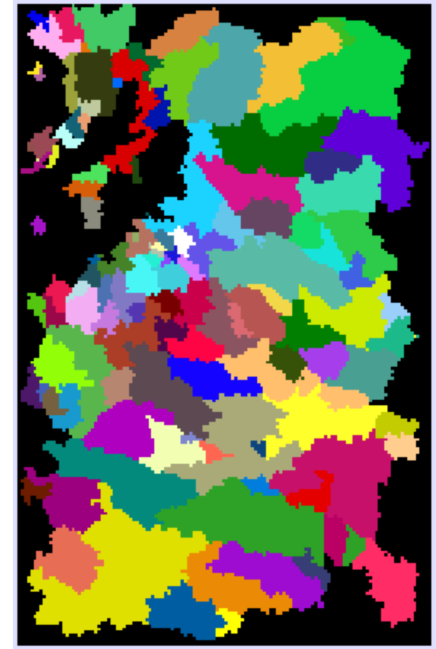
GIS and variable types in distributed models

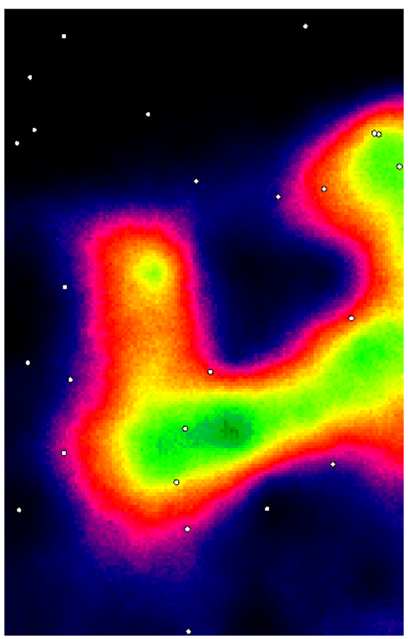
- Model variables have GIS types: Raster, point network, scalars
- Different roles in the model:
  - Static background maps (usually rasters)
  - Parameters (Adjustable information; usually scalars)
  - Input variables (time series of point or raster data)
  - States (Usually rasters, need initialisation)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

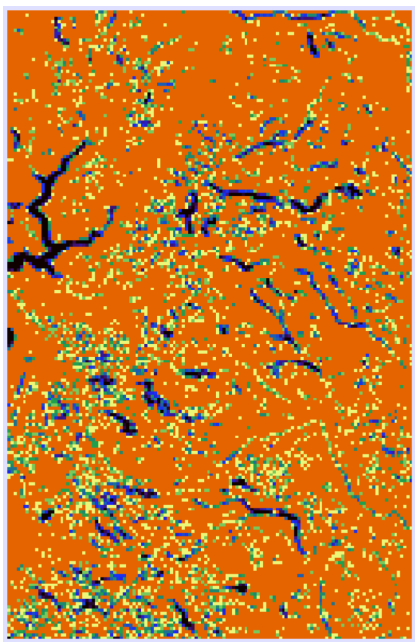
GIS based model setup:

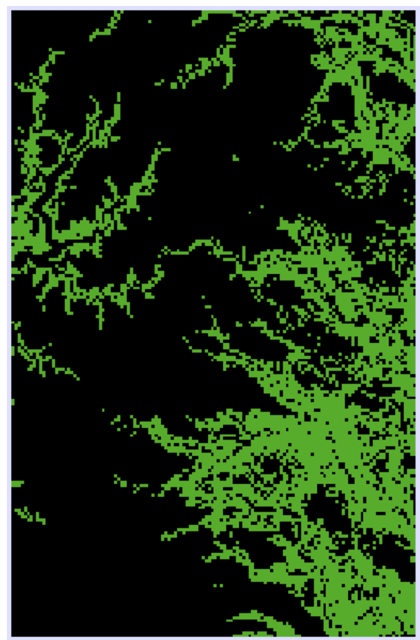
- Elevation map (DEM)
- Subcatchment division
- Measurement gauge map
- Lake map
- Forest map
- Glacier percentage map

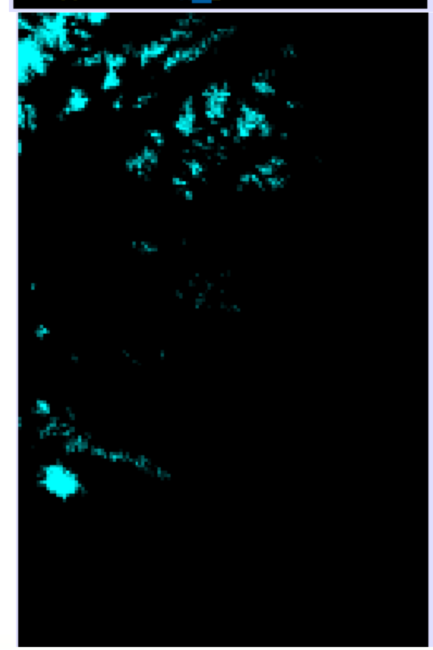




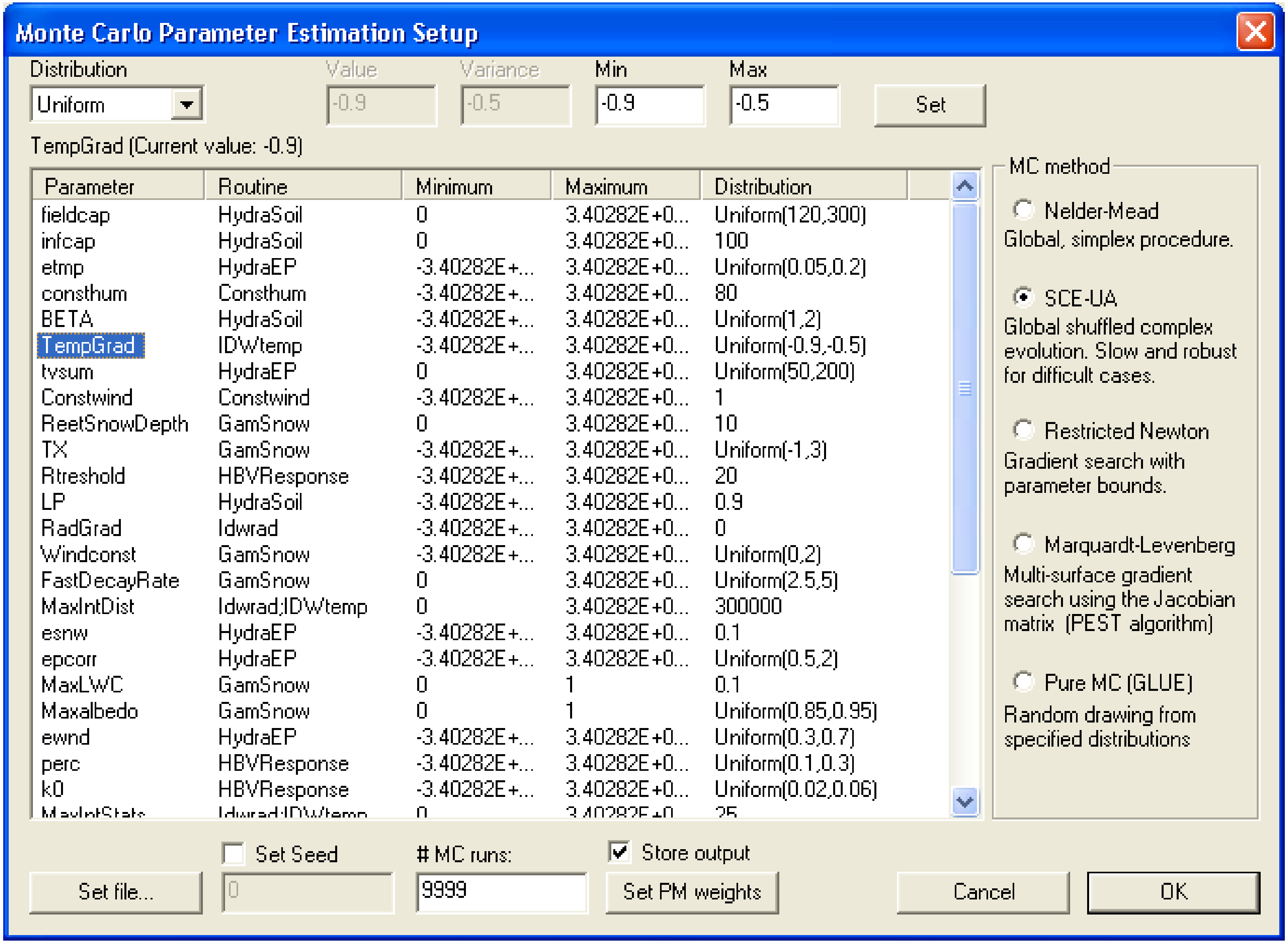






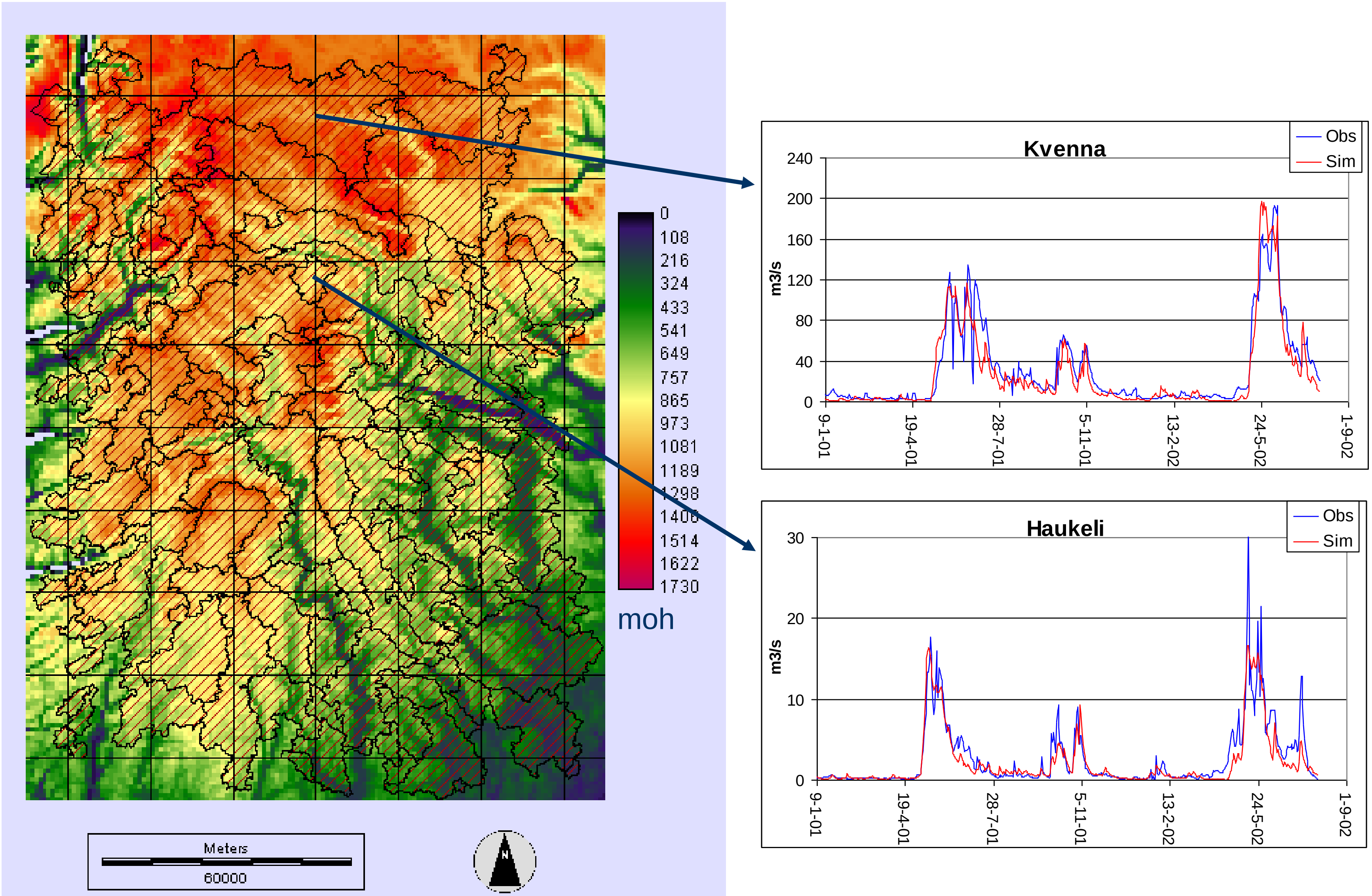


Automatic calibration



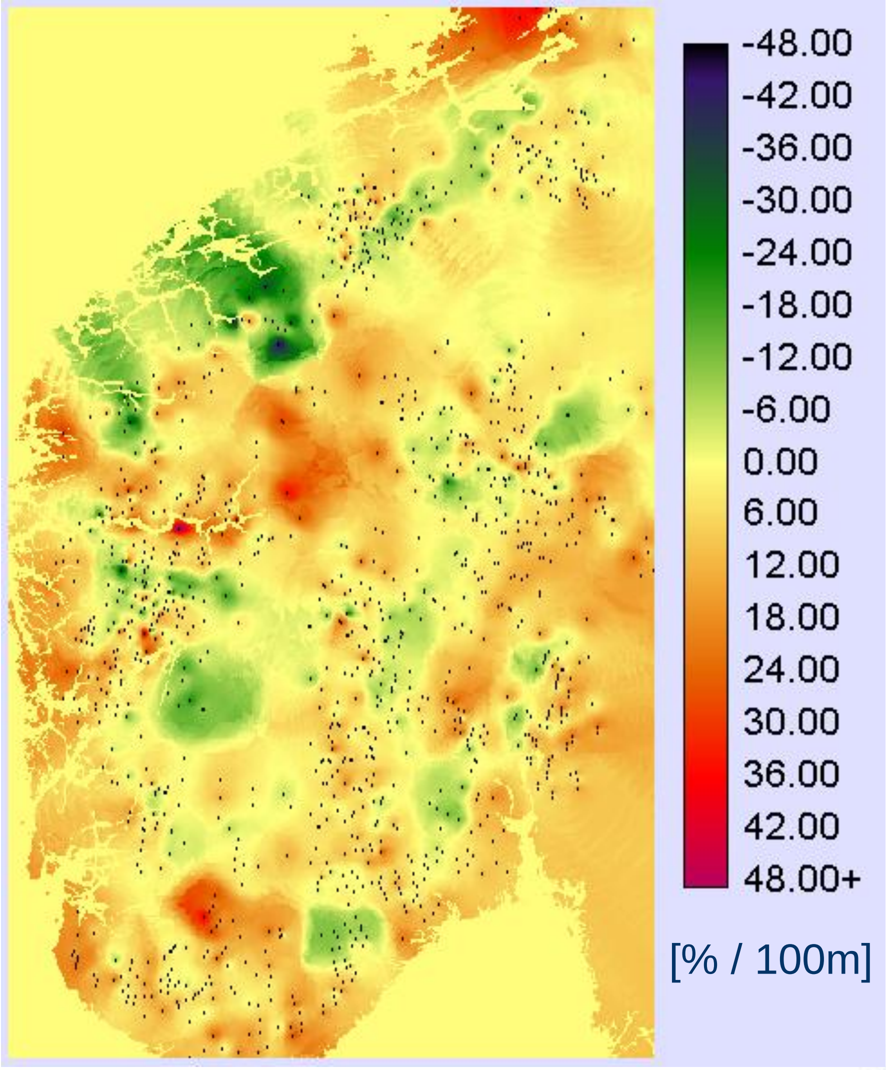
Parameter	Routine	Minimum	Maximum	Distribution
fieldcap	HydraSoil	0	3.40282E+0...	Uniform(120,300)
infcap	HydraSoil	0	3.40282E+0...	100
etmp	HydraEP	-3.40282E+...	3.40282E+0...	Uniform(0.05,0.2)
consthum	Consthum	-3.40282E+...	3.40282E+0...	80
BETA	HydraSoil	-3.40282E+...	3.40282E+0...	Uniform(1,2)
TempGrad	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	HBVResponse	-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	HBVResponse	-3.40282E+...	3.40282E+0...	Uniform(0.1,0.3)
k0	HBVResponse	-3.40282E+...	3.40282E+0...	Uniform(0.02,0.06)
MaxIntStats	Idwrad;IDWtemp	0	3.40282E+0...	25

Regional simulation and calibration

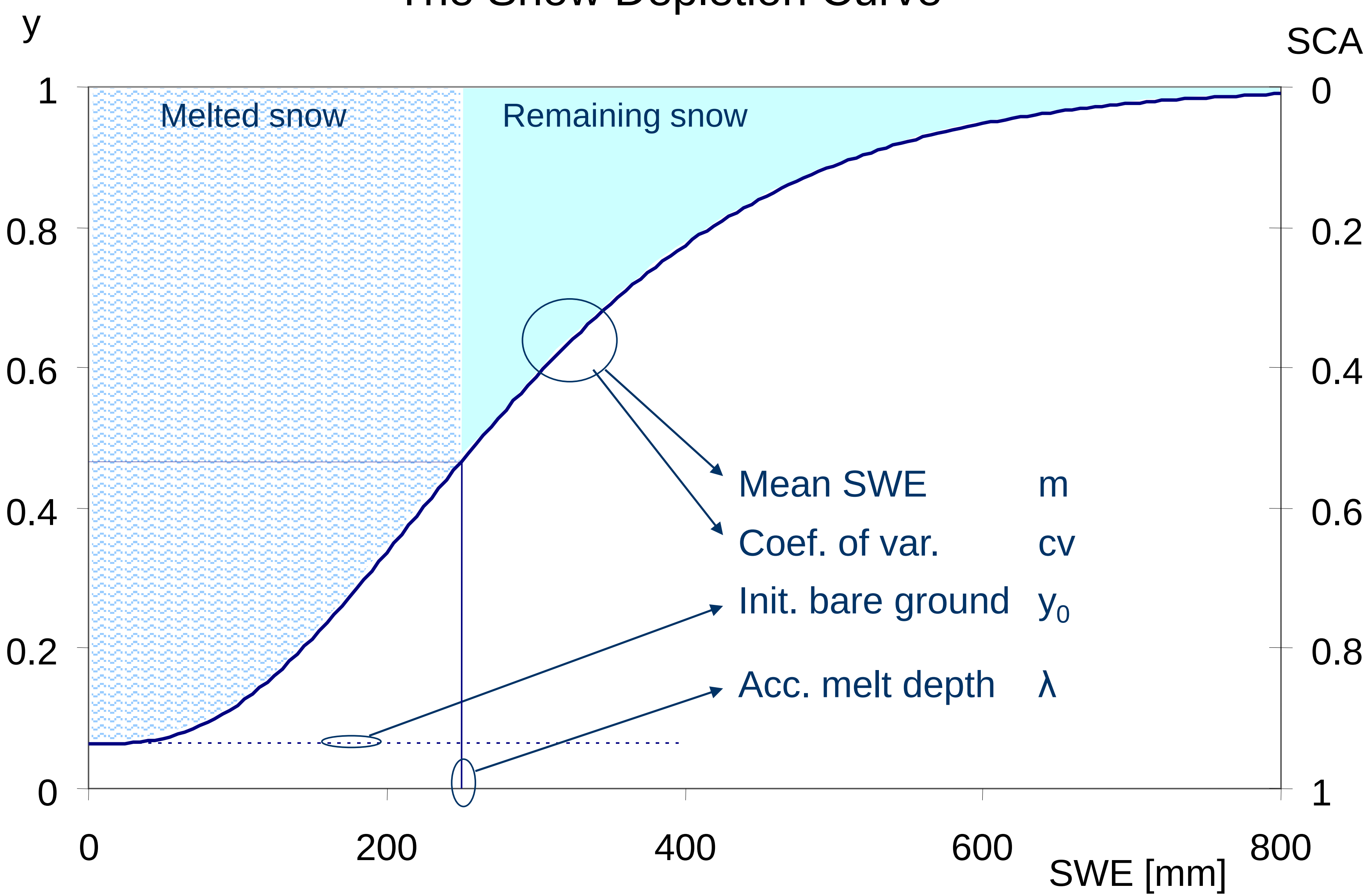


Regional pattern in the elevation dependency of precipitation?

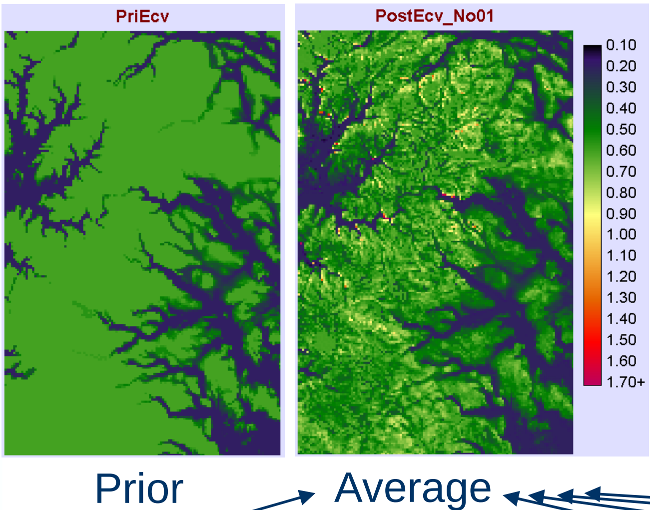
- Long-term all-region average precipitation lapse rate:
  3.6 +/- 0.29 [% / 100m]
- A considerable part of the variation follows regional patterns
- Some places show strong variability over short distances
- Some extreme values may depend on a single or a few stations.



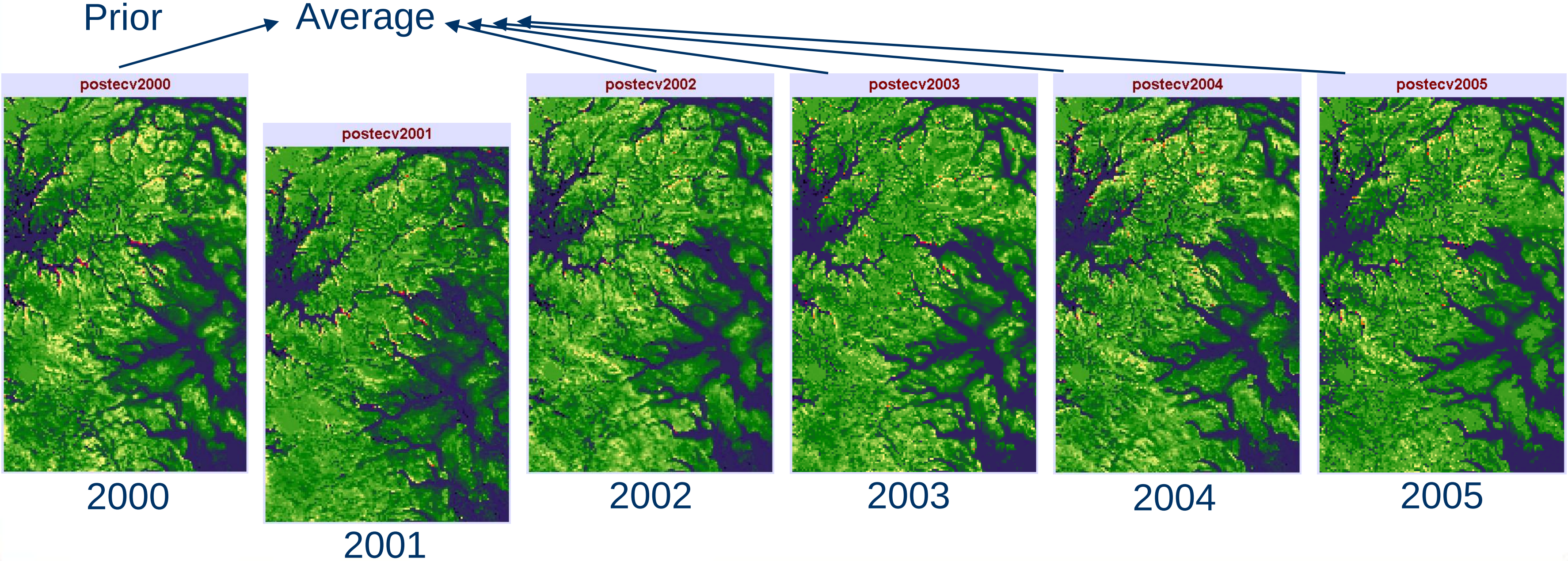
The Snow Depletion Curve



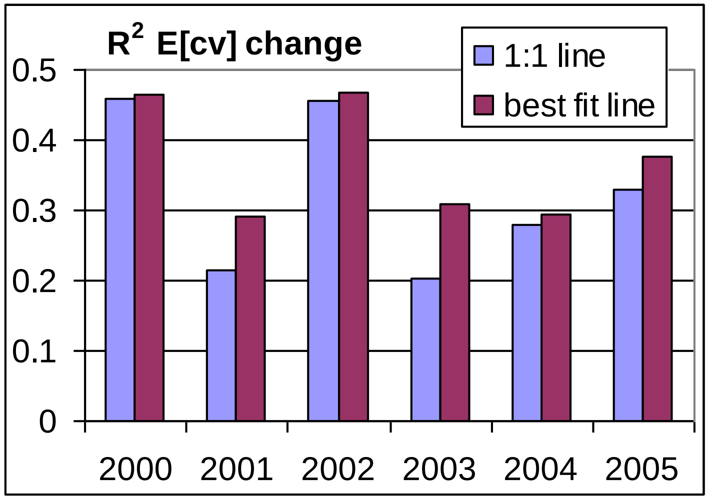
Results: Sub-grid heterogeneity *CV*

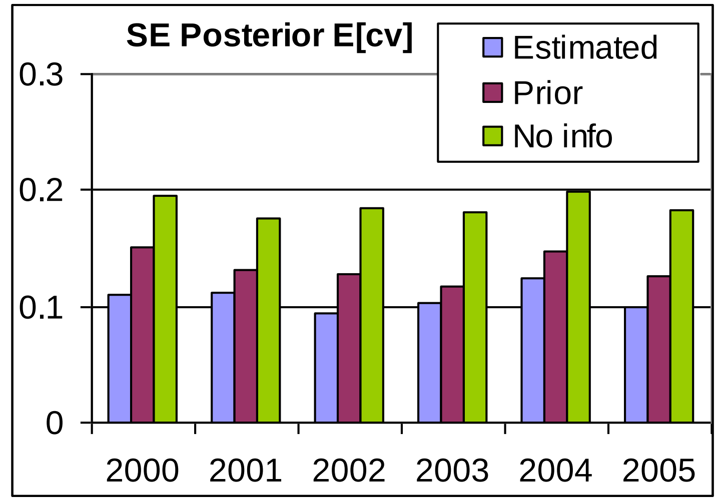


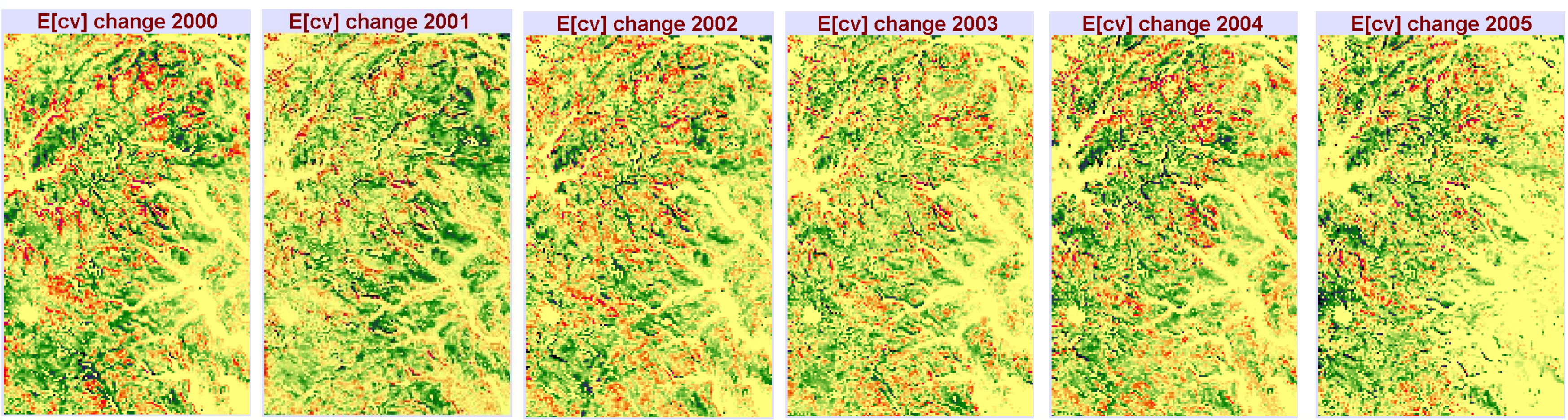
- Prior expectation depending on forest
- Each year a posteror expectation
- Average to estimate a calibrated map
- Evaluate using the left-out year



Cross-validation results, CV





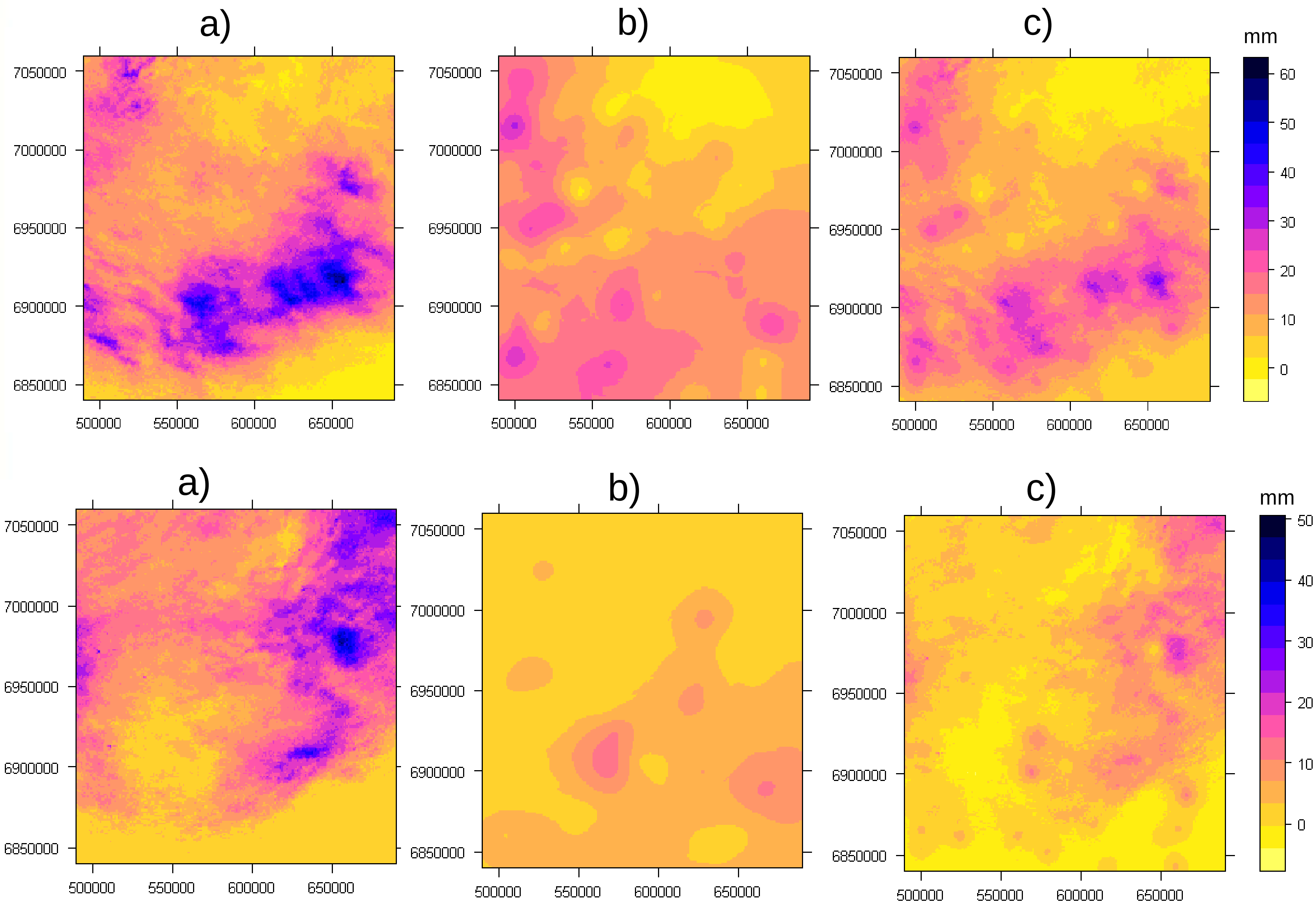


Uncertainty in point precipitation data

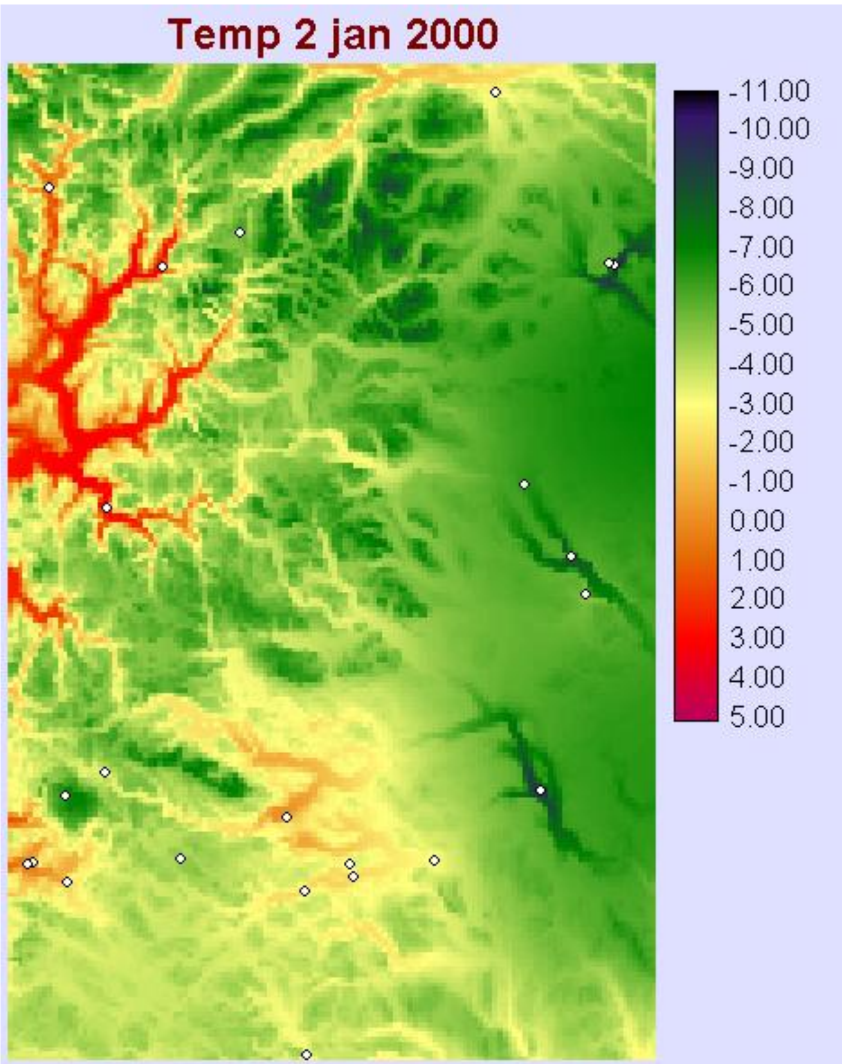
Correction	Wind hour	Wind day	Exp kl. 1	Exp kl. 2	Exp kl. 3	Exp kl. 4	Exp kl. 5
Summer	0.06	0.03	0.05	0.07	0.09	0.12	0.18
Winter	0.08	0.03	0.09	0.23	0.32	0.40	0.51

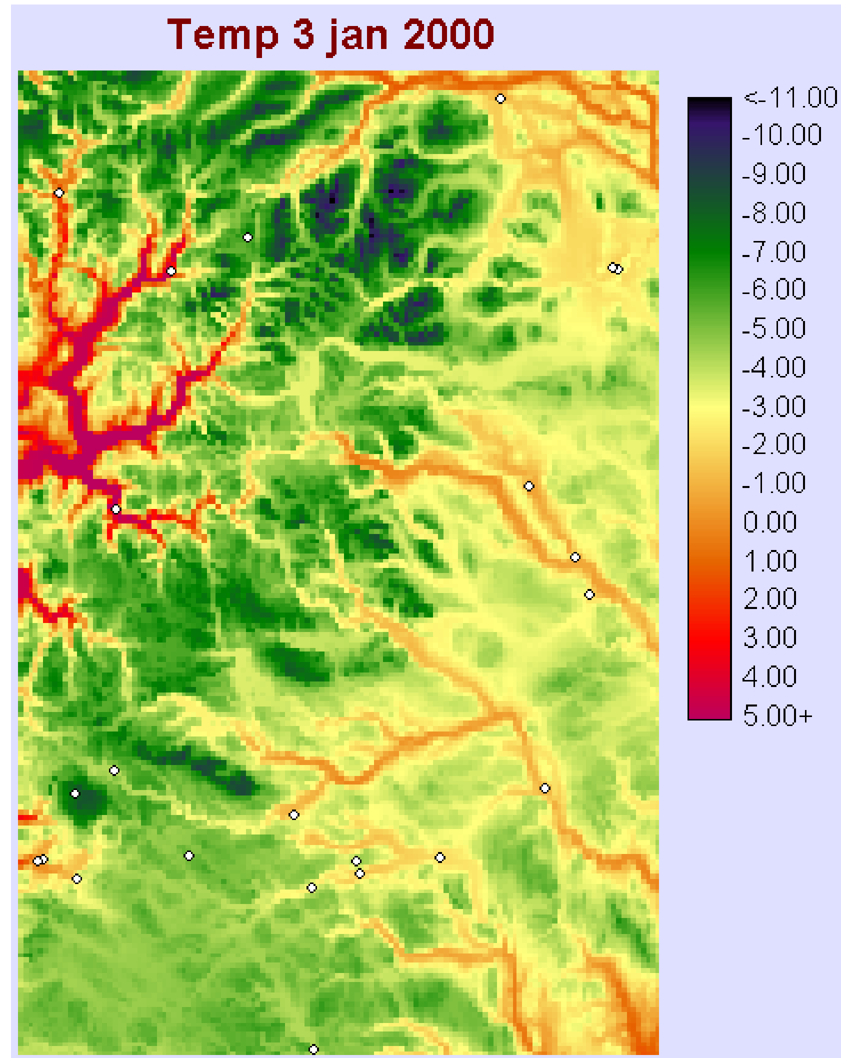
State of weather radar project

- 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


a)
b)
c)
mm
7050000
7000000
6950000
6900000
6850000
500000
550000
600000
650000
60
50
40
30
20
10
0
a)
b)
c)
mm
50
40
30
20
10
0

Temperature interpolation





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