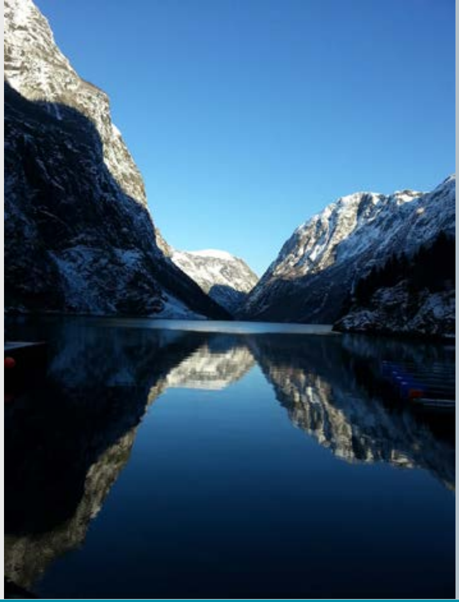
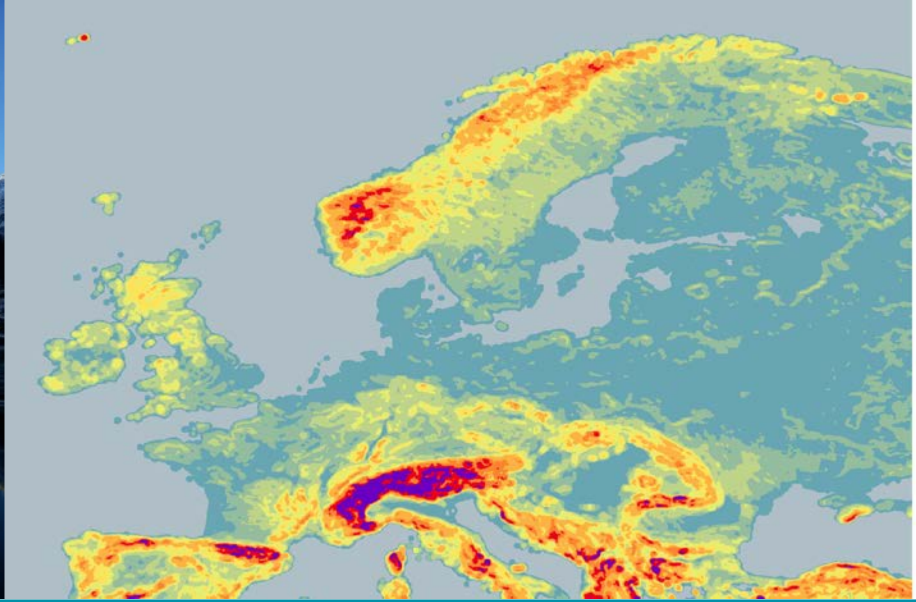




Observation based gridded climate data in Norway –

motivations, experiences, challenges, considerations…..

Ole Einar Tveito and Cristian Lussana

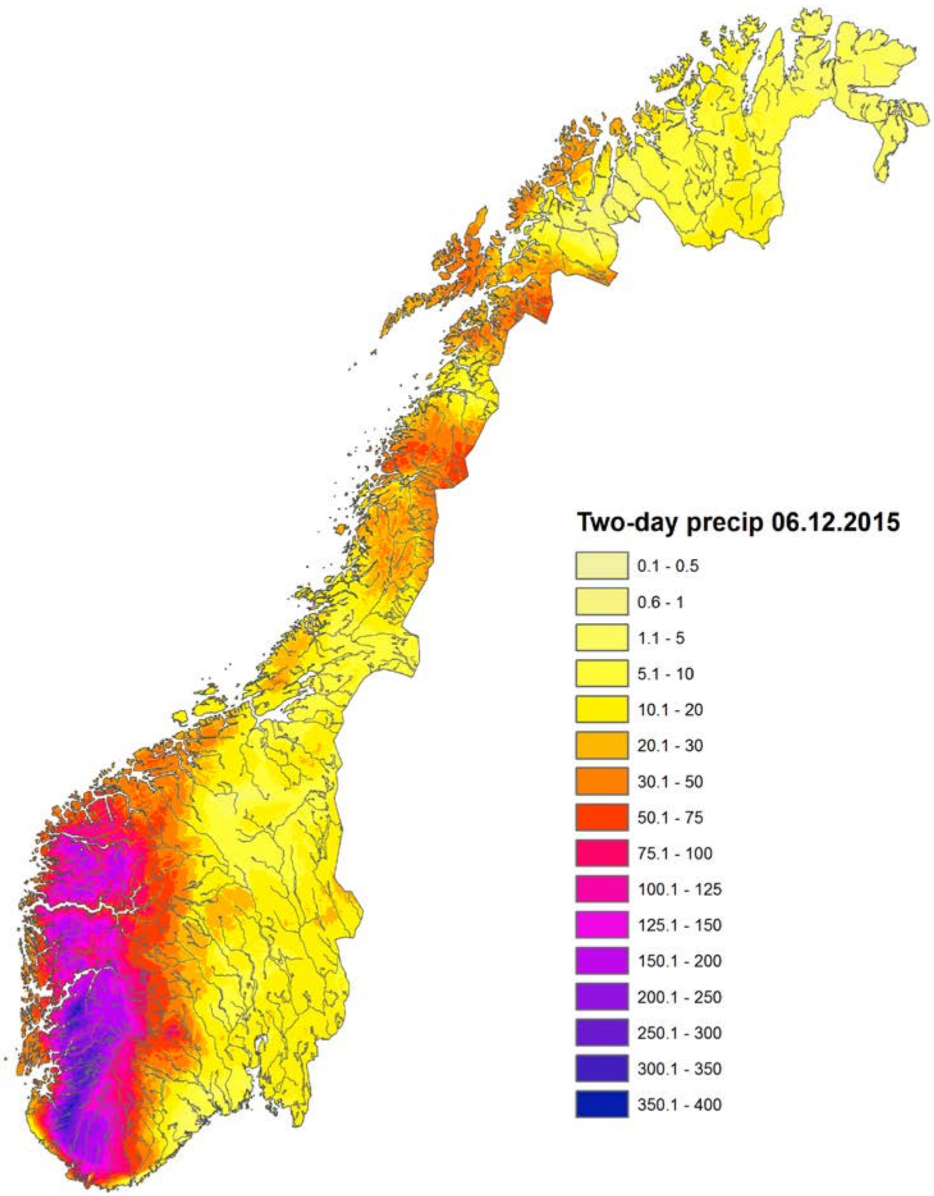

Foto: MORTEN AAKRE, FOTOGRAFEN AS EGERSUND


Photo:Tor Magne Gausdal

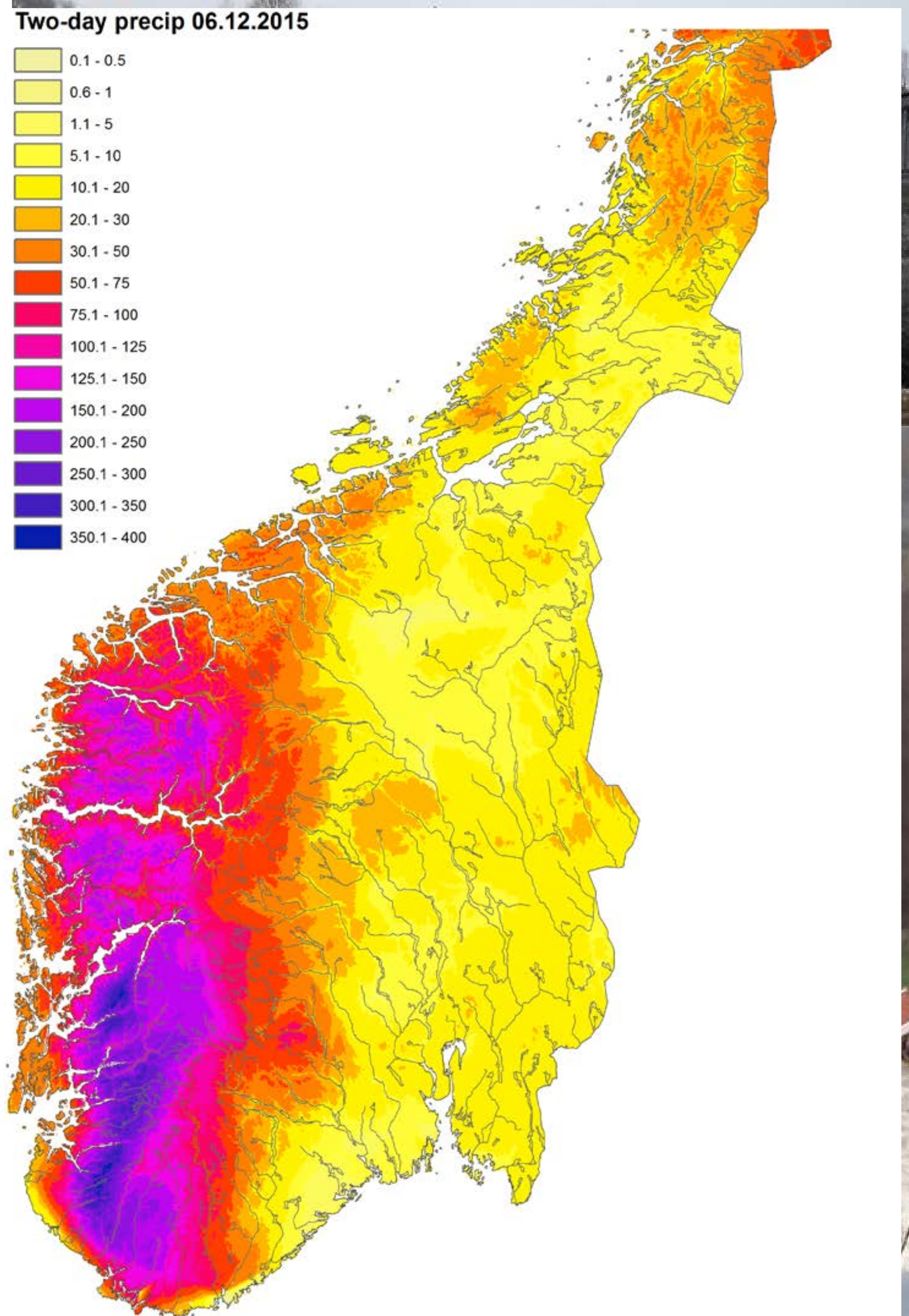
Foto: CARINA JOHANSEN, VG


Foto: Svanhild Eilertsen Lervik


Kilde: NRK



Two-day precip 06.12.2015
0.1 - 0.5
0.6 - 1
1.1 - 5
5.1 - 10
10.1 - 20
20.1 - 30
30.1 - 50
50.1 - 75
75.1 - 100
100.1 - 125
125.1 - 150
150.1 - 200
200.1 - 250
250.1 - 300
300.1 - 350
350.1 - 400



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125.1 - 150
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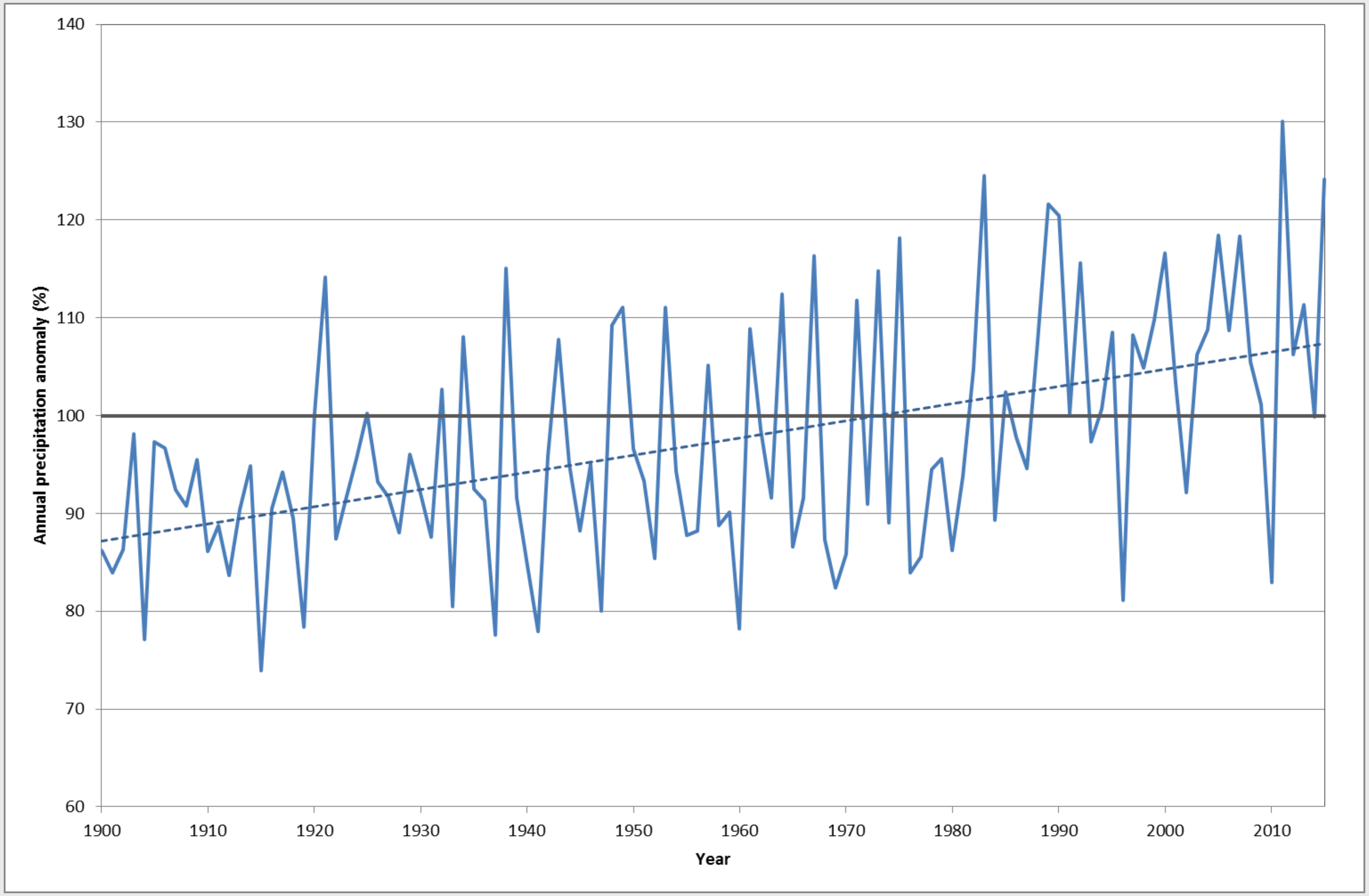
200.1 - 250
250.1 - 300
300.1 - 350
350.1 - 400

Precipitation



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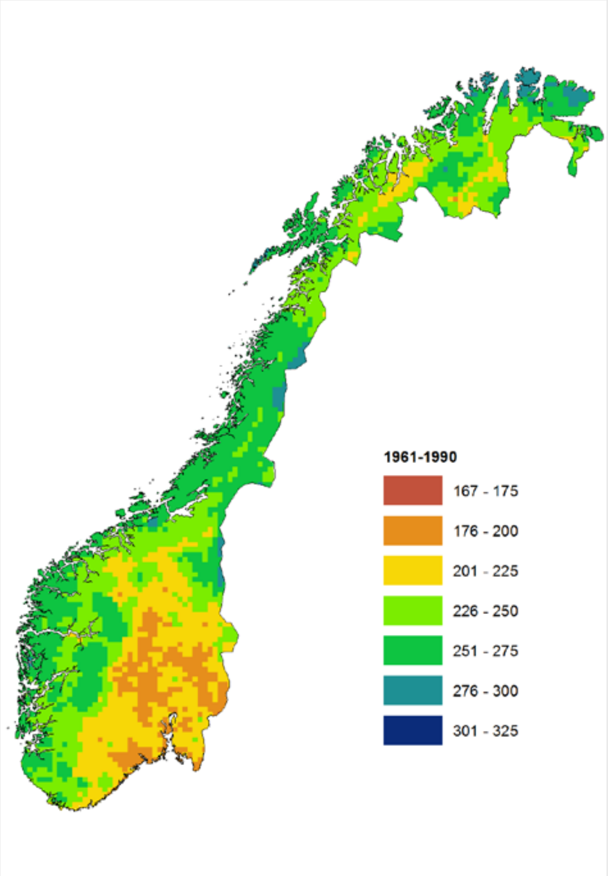
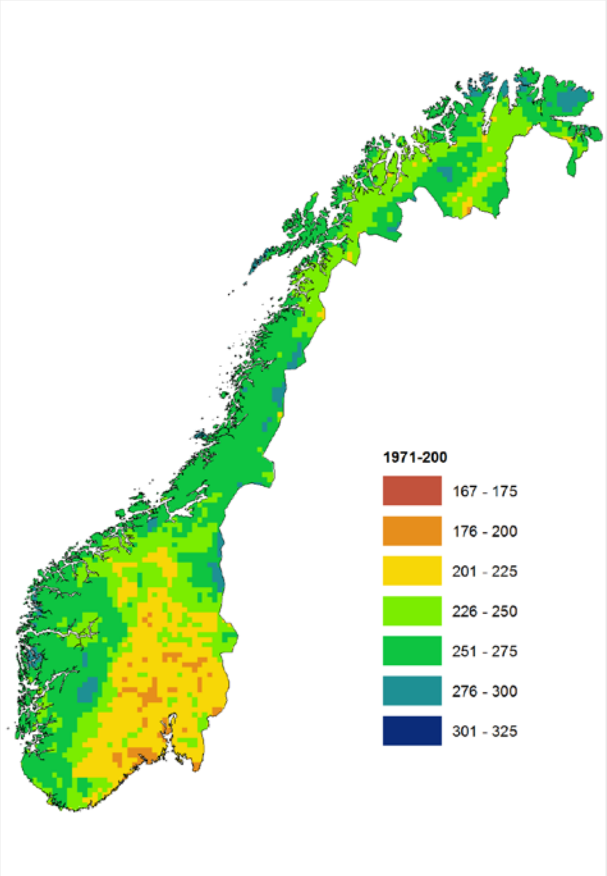
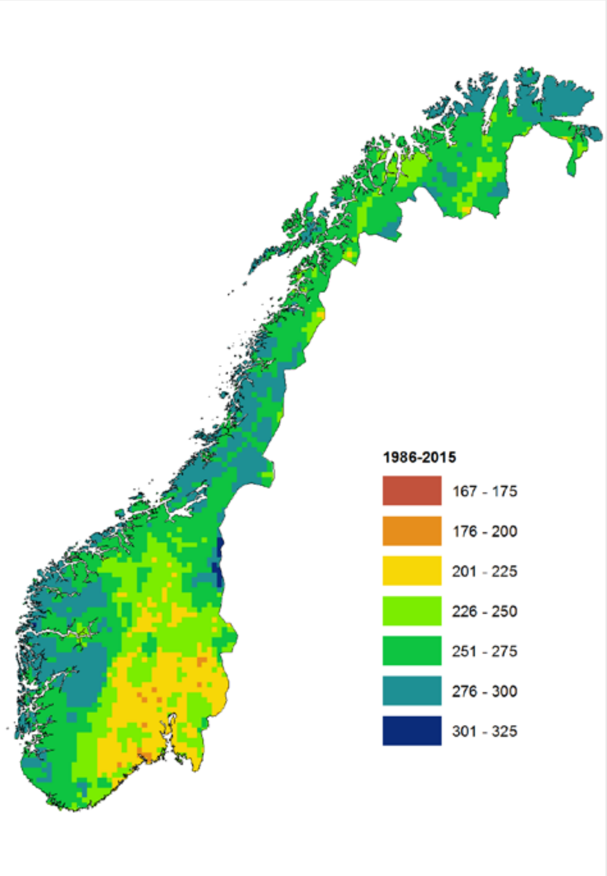
Days with precipitation







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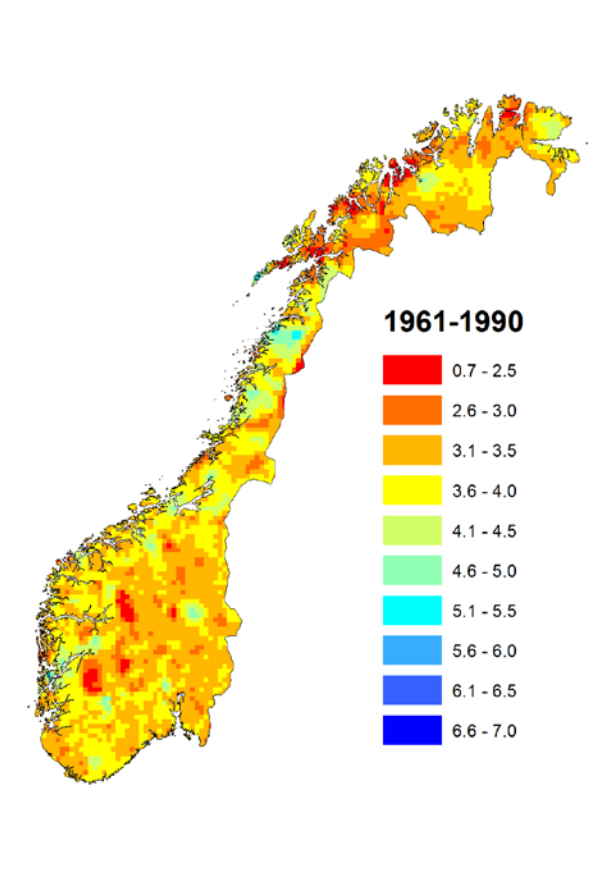
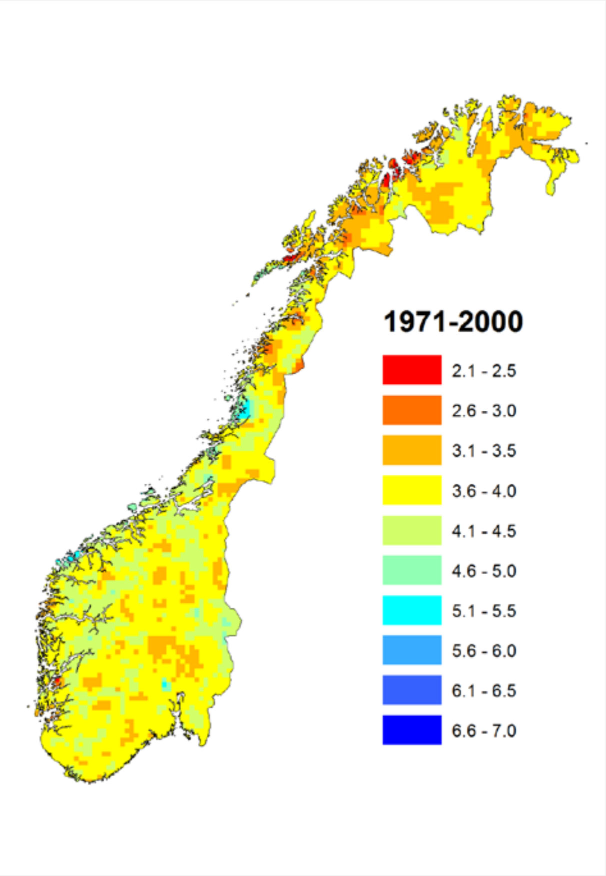
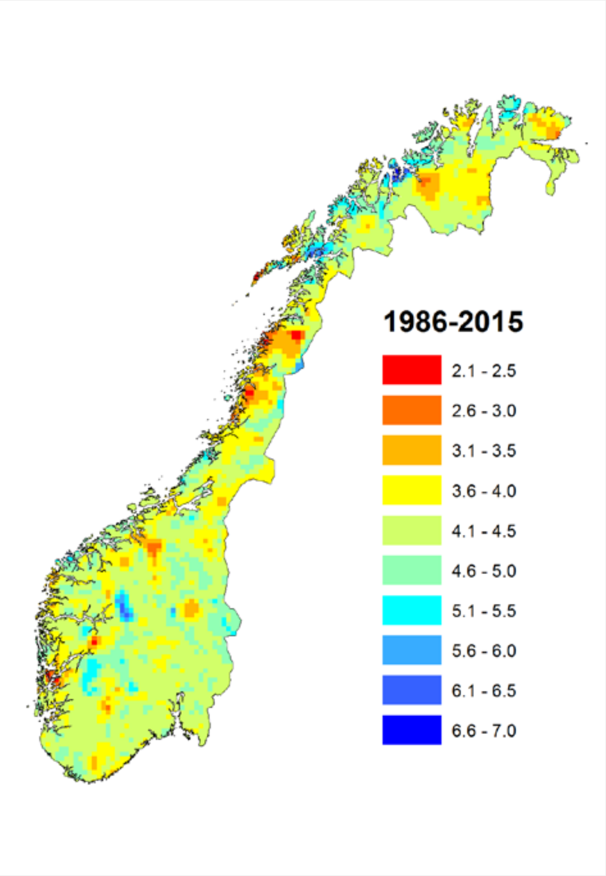
Number of days > p(0.99)







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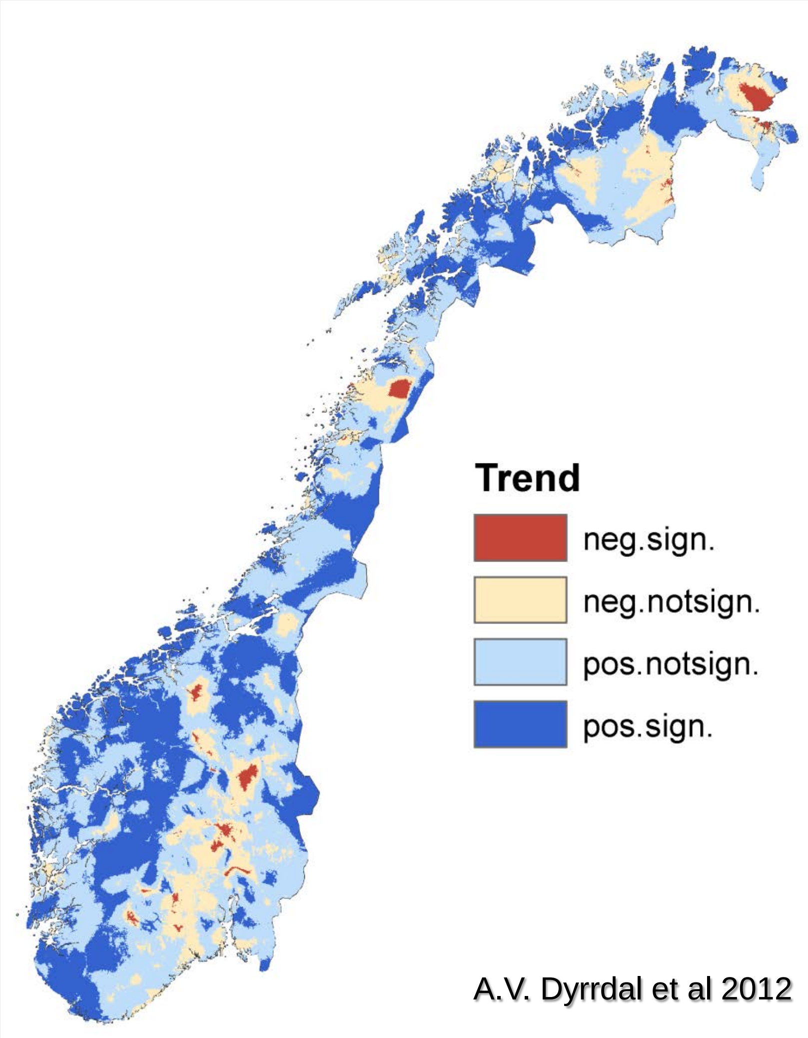
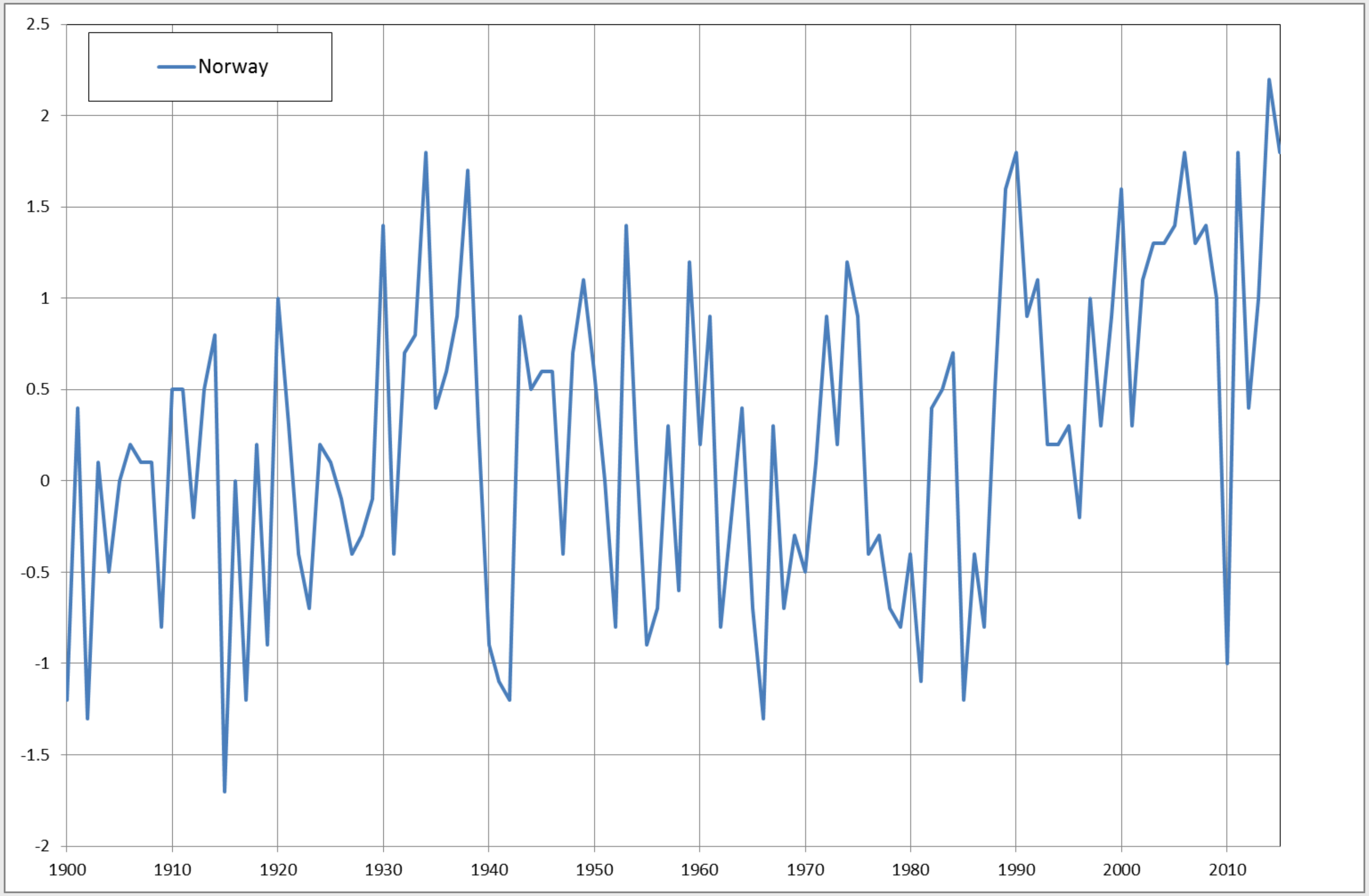
Trends in 1-day precipitation exceeding 10 mm



Dyrrdal, A.V., Isaksen, K., Hygen, H.O., and Meyer, N.K., 2012: Changes in meteorological variables that can trigger natural hazards in Norway. Climate Research, 55: 153–165

Norwegian annual temperatures



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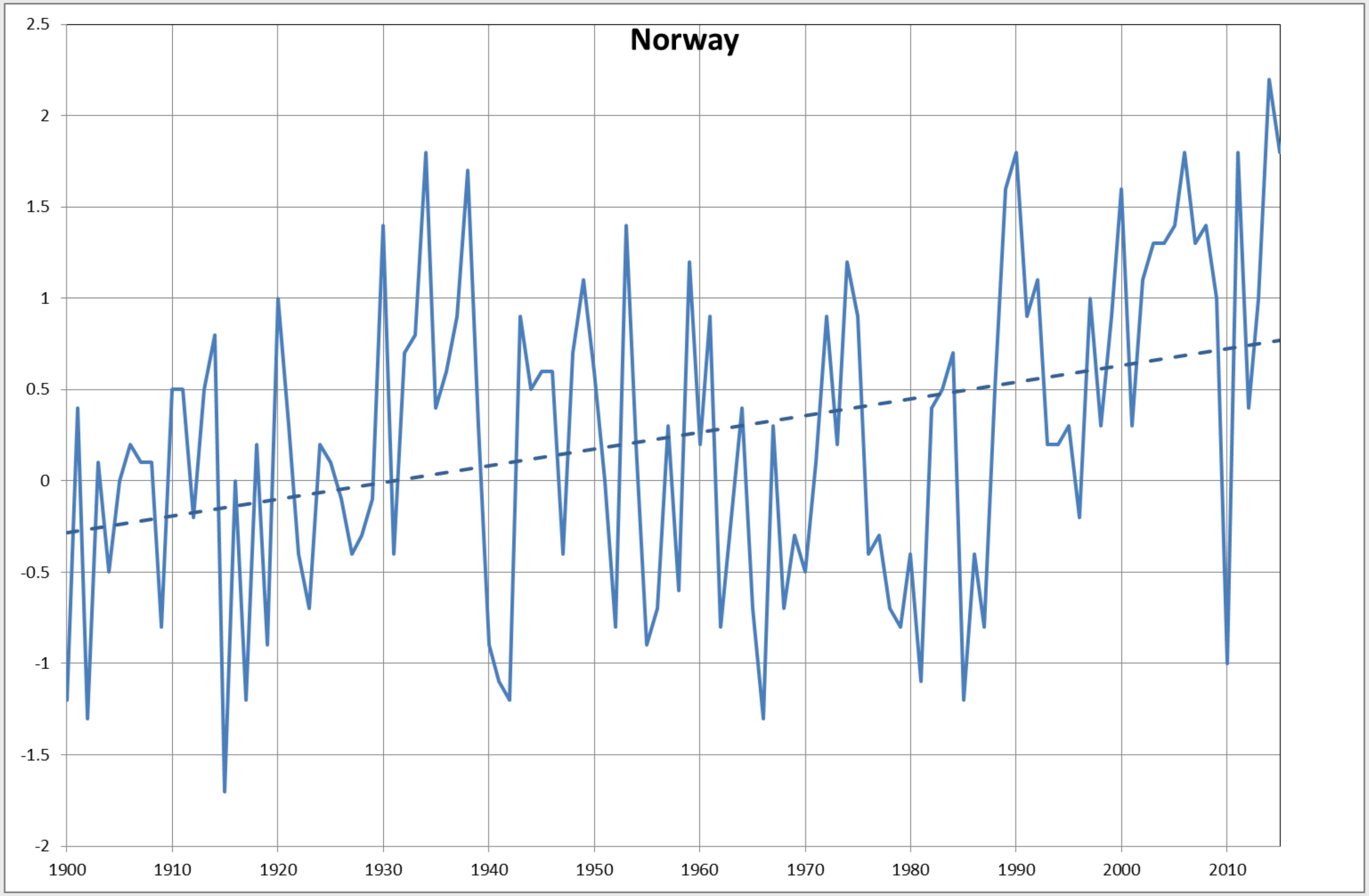
Norwegian annual temperatures



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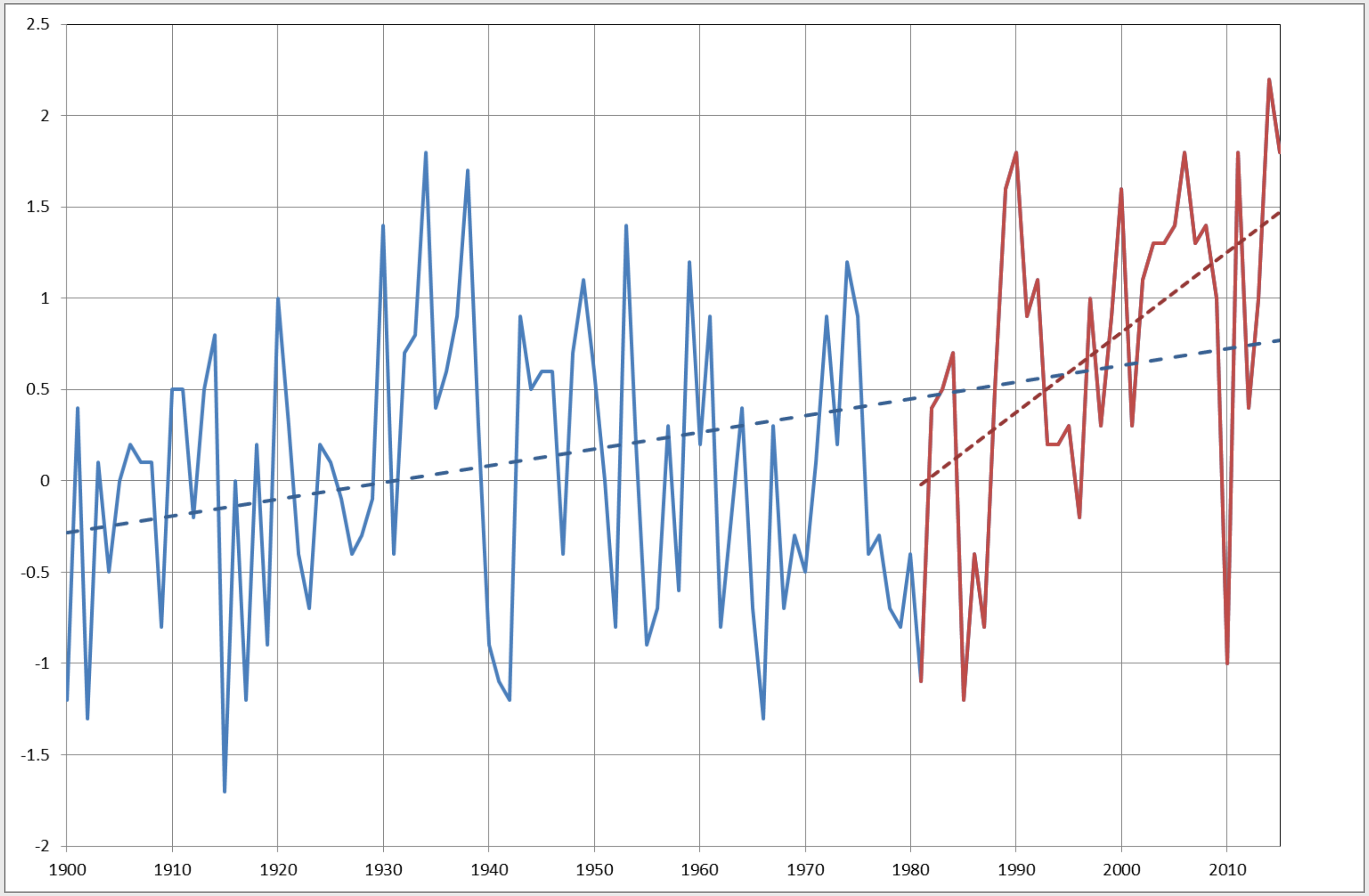
Norwegian annual temperatures



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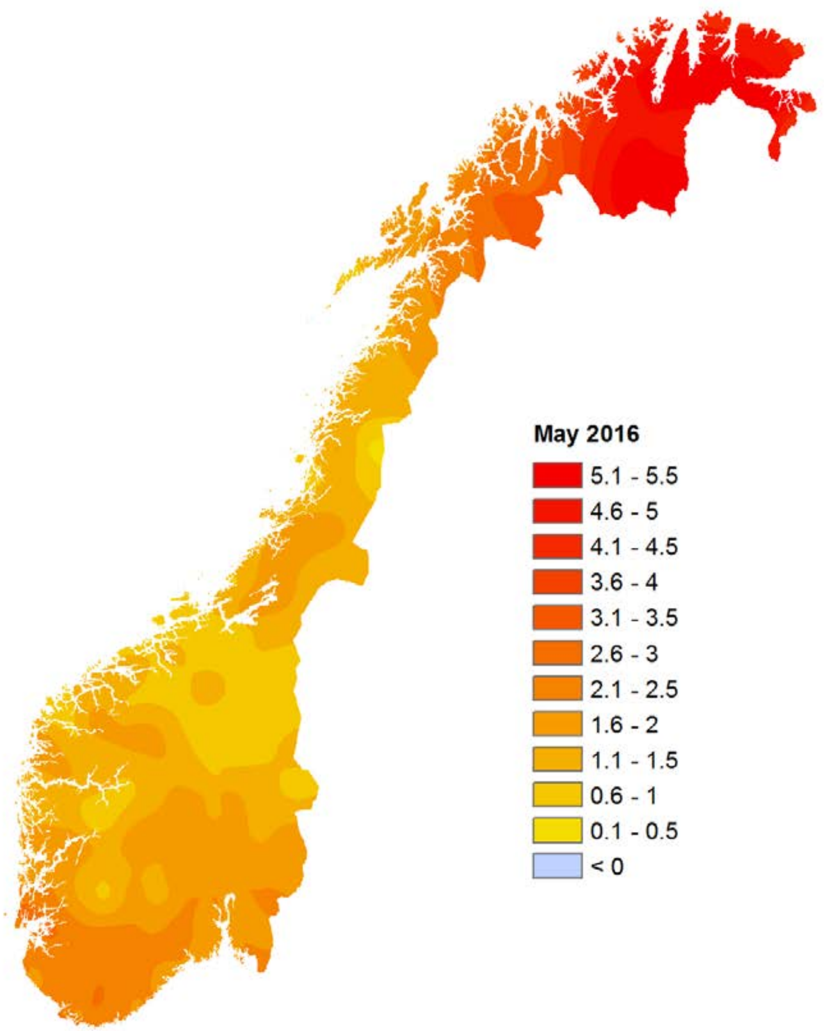

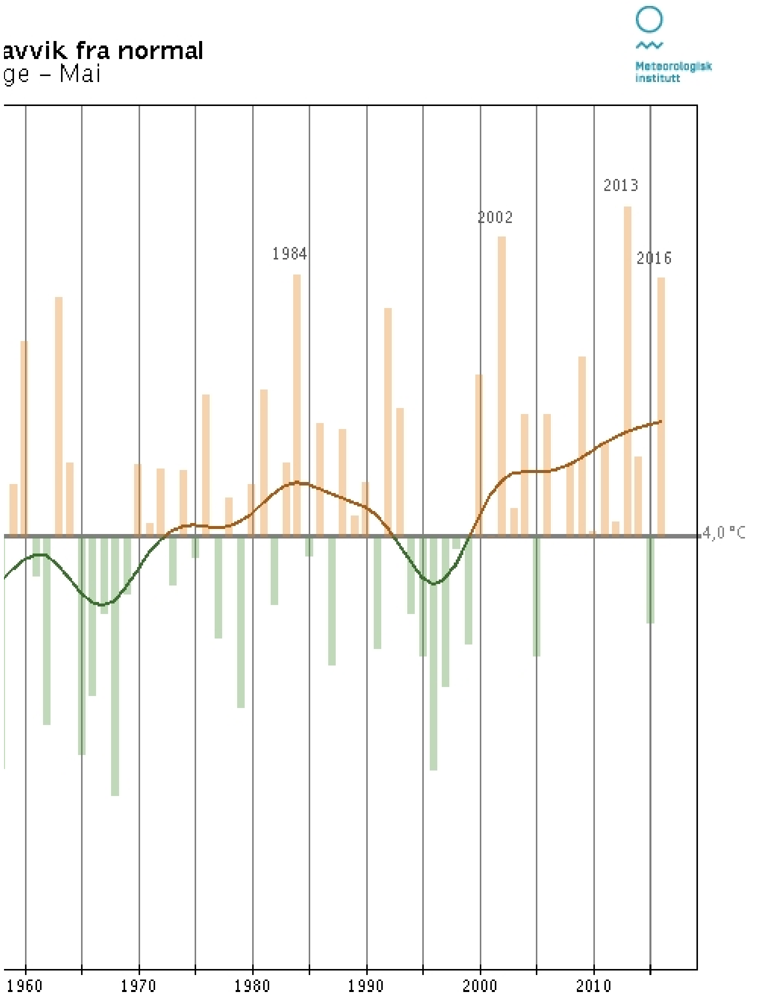

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Gridding of observation - aims to

- Provide *climate information* at any location or area of interest

- Provide data at *relevant scales* for various applications and purposes:
  - Hydrology
  - Agriculture and forestry
  - Infrastructure (roads, railways, electricity grids, municipalities)
  - Dam safety
  - Energy
  - Tourism
  - ….

← Design values

- Provide a observation basis for *understanding* and *adapting* to ***climate change***

- “Truth” for calibrating post-processing (bias adjustment) of RCM / Dyn.Downscaling of climate projection data.

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Gridded observation data sets at Met Norway.

- Monthly, seasonal and annual data
  - Period: 1900-present
  - Variables: Temperature, Precipitation
  - Methods: Spline interpolation of monthly anomalies.
  - Derived products: Degree day grids.

- Daily values (two parallel datasets)
  - Period: 1957 - present
  - Variables: Temperature, Precipitation, Wind (in development)
  - Methods:
    - Ver.1: Residual Kriging (temperature), Triangulation with terrain dependence (precipitation)
    - Ver. 2: Bayesian spatial optimum interpolation (under operationalization)
    - Wind: Downcaling/post-processing of Hindcast data applying analogues from high res NWP-model and smart neighbour weighting
  - Datasets covering Fennoscandia based on both ver.1 and 2 are in progress as a part of the FP7 UERRA project.

- Hourly values
  - Period: 2010-present
  - Variables: Temperature and precipitation
  - Bayesian spatial optimum interpolation (under operationalization)

- Spatial resolution: 1x1 km

- Access: Open data

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What makes observation gridding challenging?

- Resolution
  - Spatial – sampling problem.
  - Temporal – signal to noise ratio.

- Observation density and representativity

  Networks are
  - Sparse
  - Biased
    - Elevation zones
    - Environment/Land Use: Are the environments of the observation stations representative for all types of environments? (Open field vs. forests or cities?)

- Statistical assumption vs physical processes
  - Assume stationarity (2.order spatial …)
  - Assume isotropy

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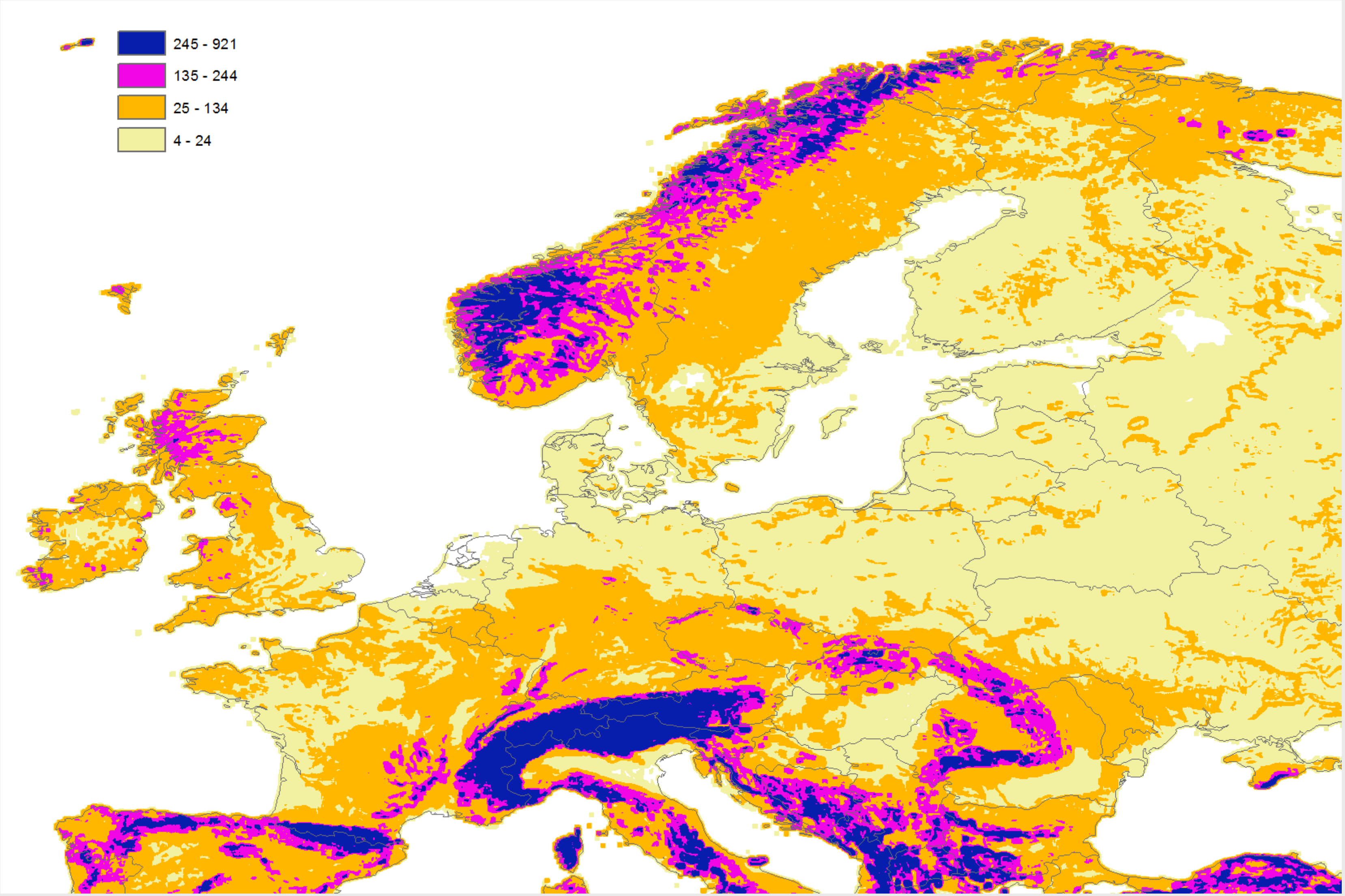
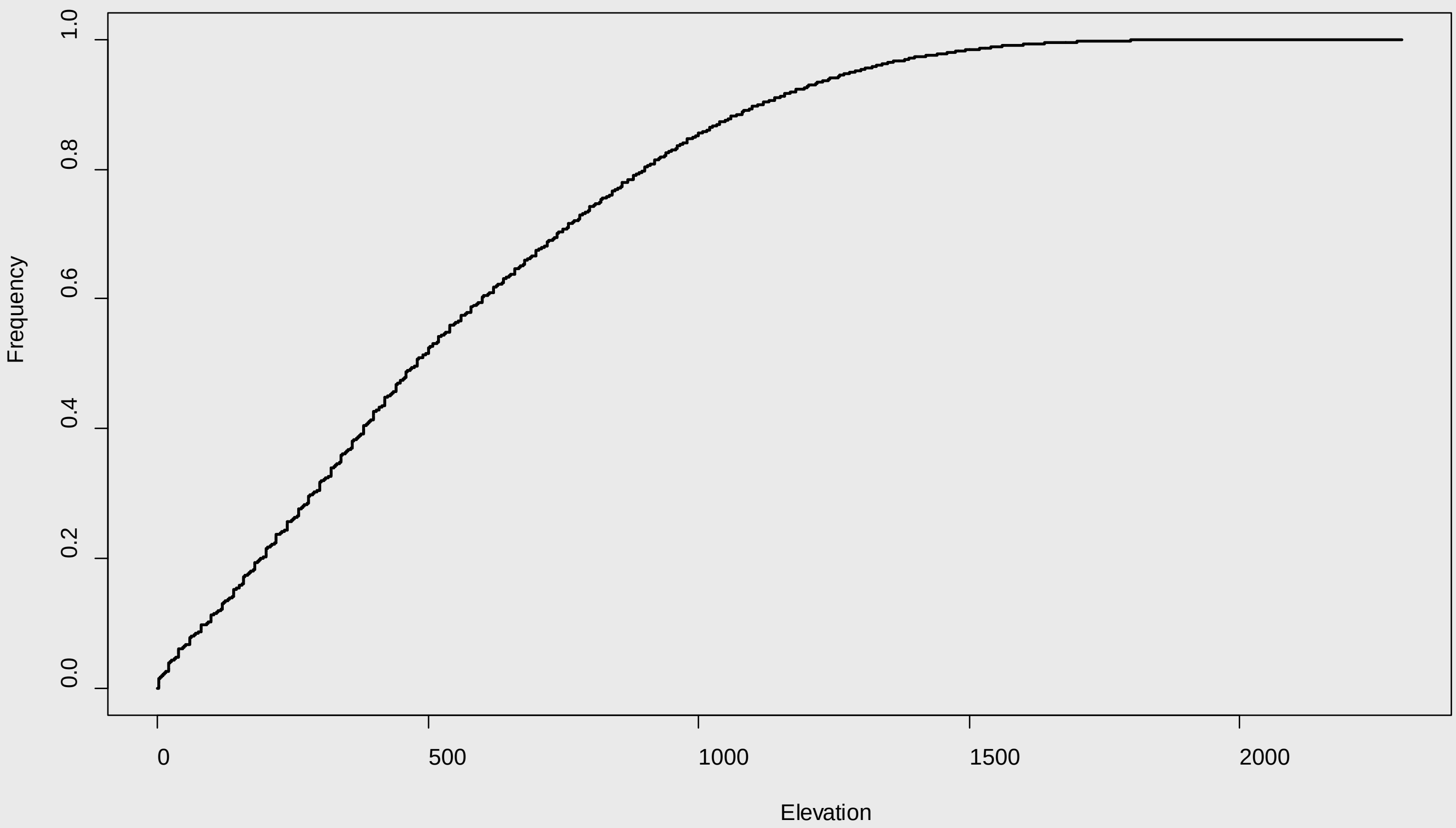
Elevation

Standard deviation of terrain

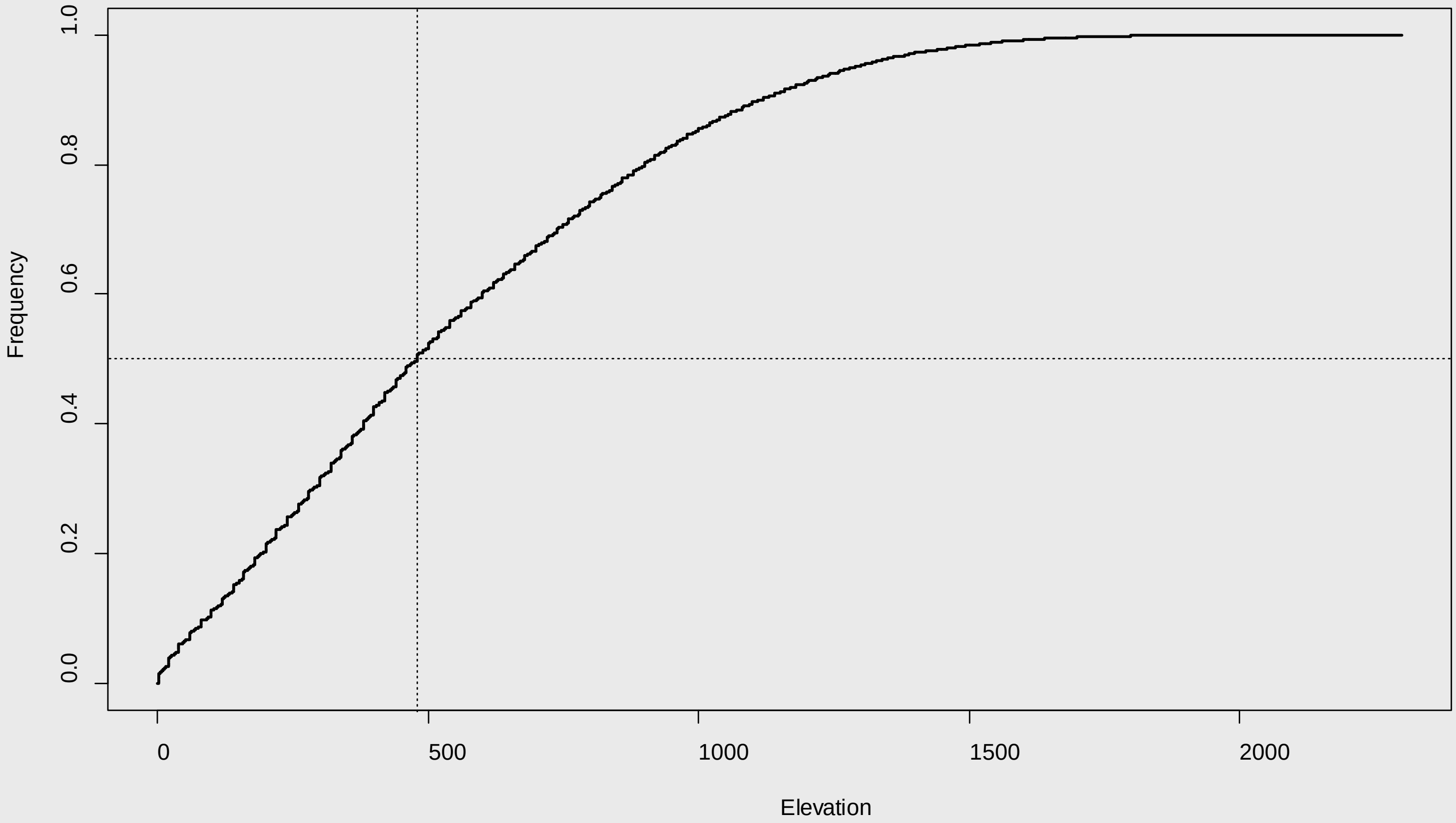
~10 km influence area



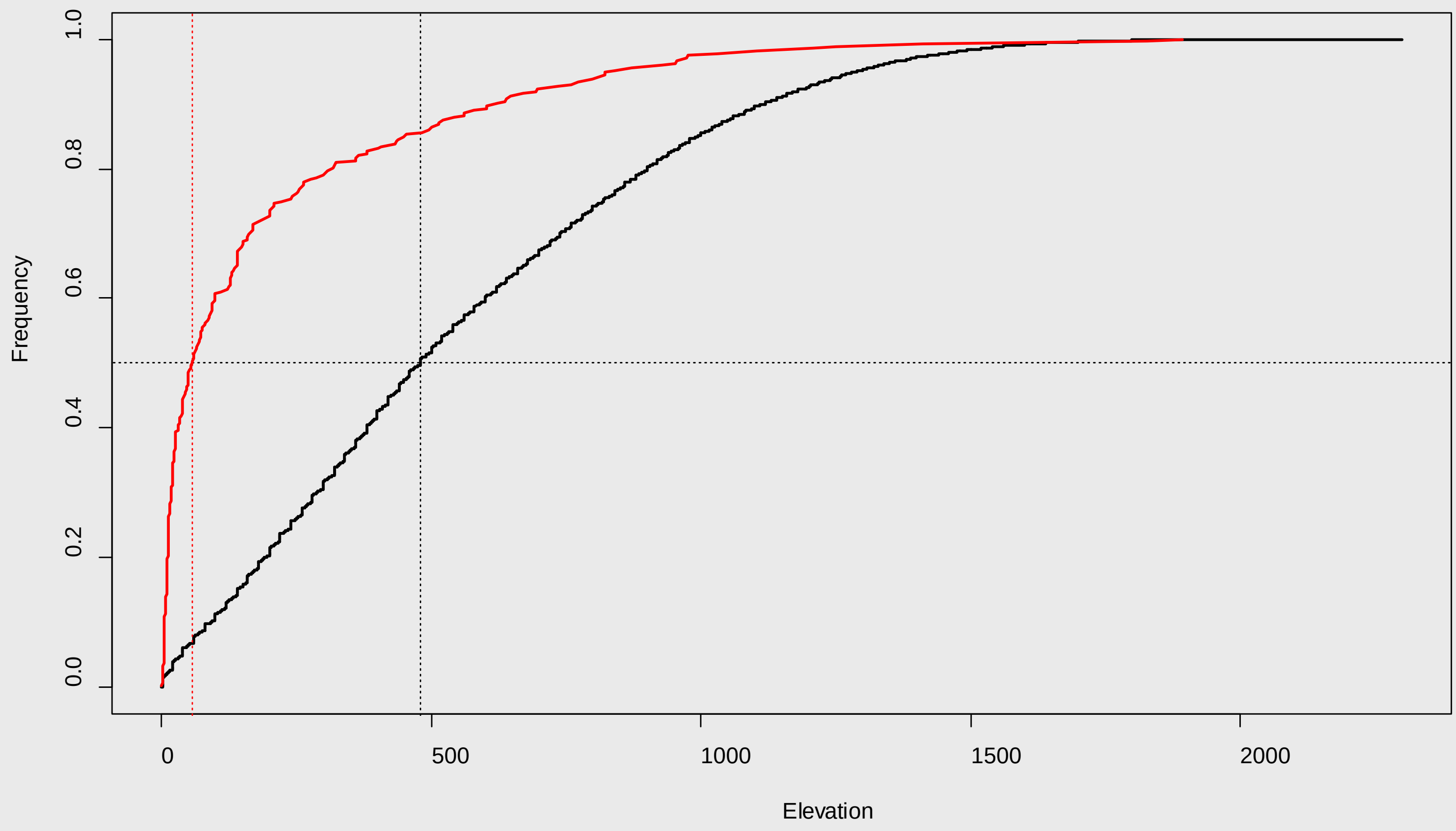
The distribution of elevation



The distribution of elevation



The distribution of elevation & temperature stations



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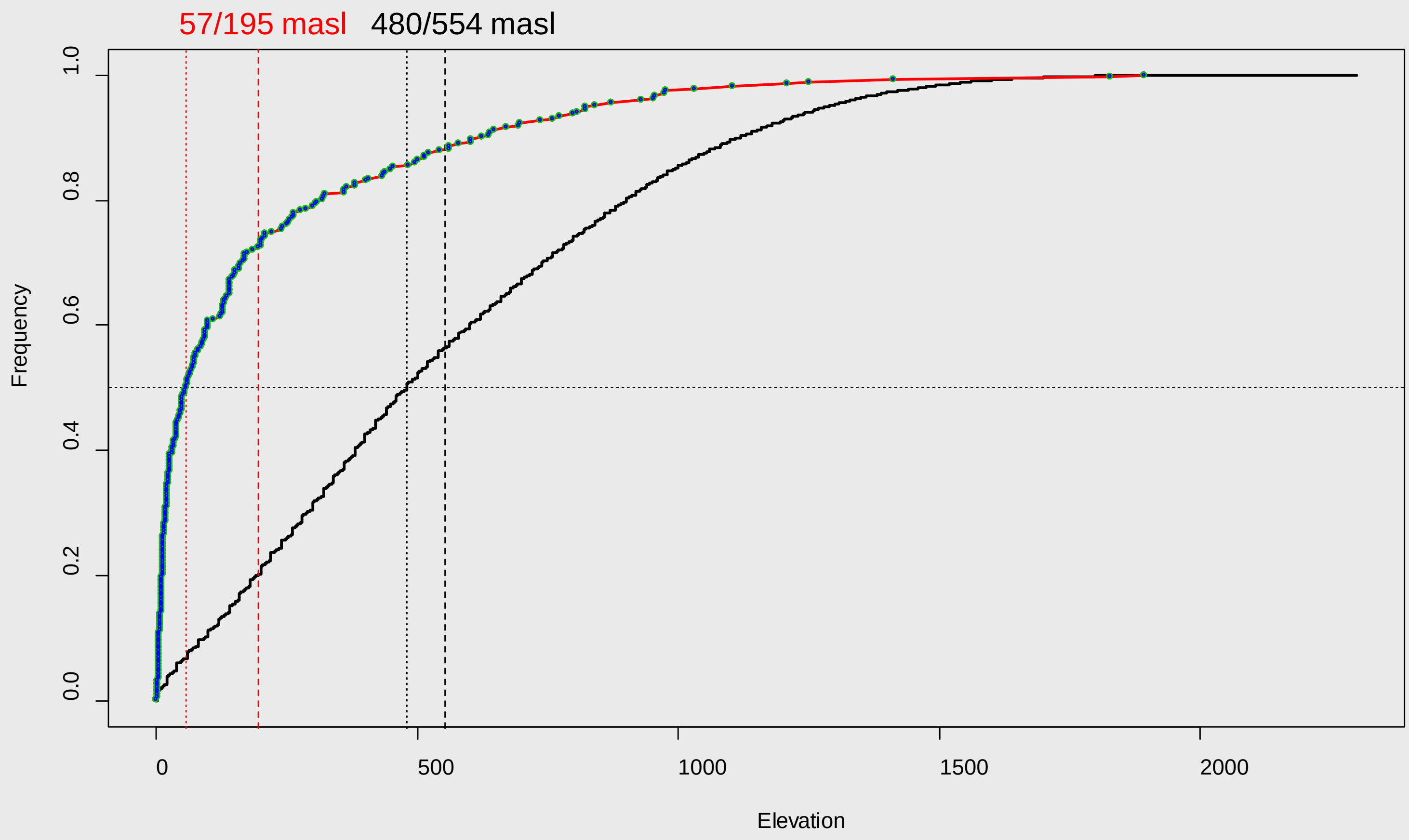
The distribution of elevation & temperature stations



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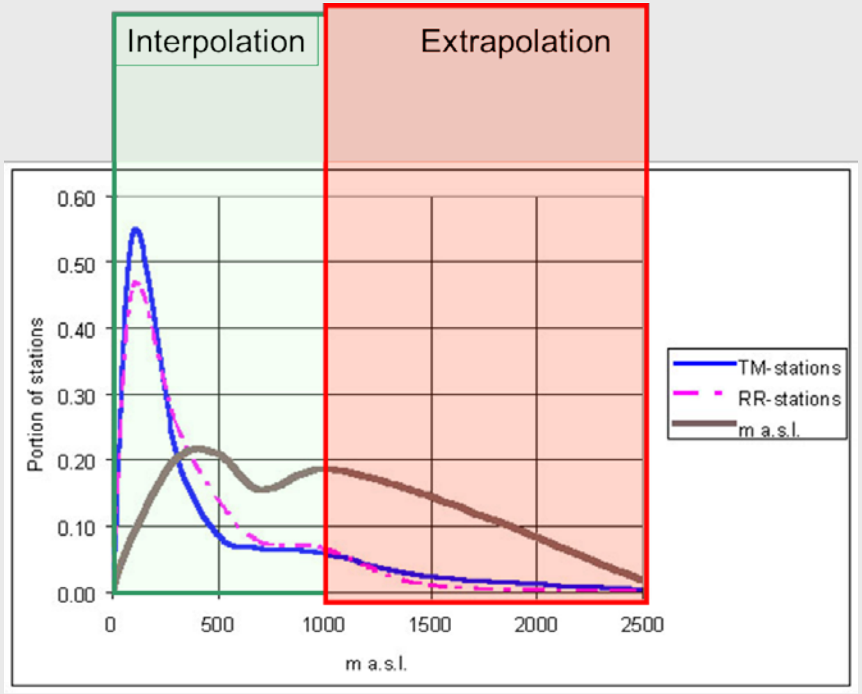
Gridding challenges (i)

- Observation gridding is basically based on statistical relations
  - Quality depends on **station density** and **representativity** of the station network.



- The choice of external predictor should be based on a good understanding of the physical processes of the predictand (on a local scale).

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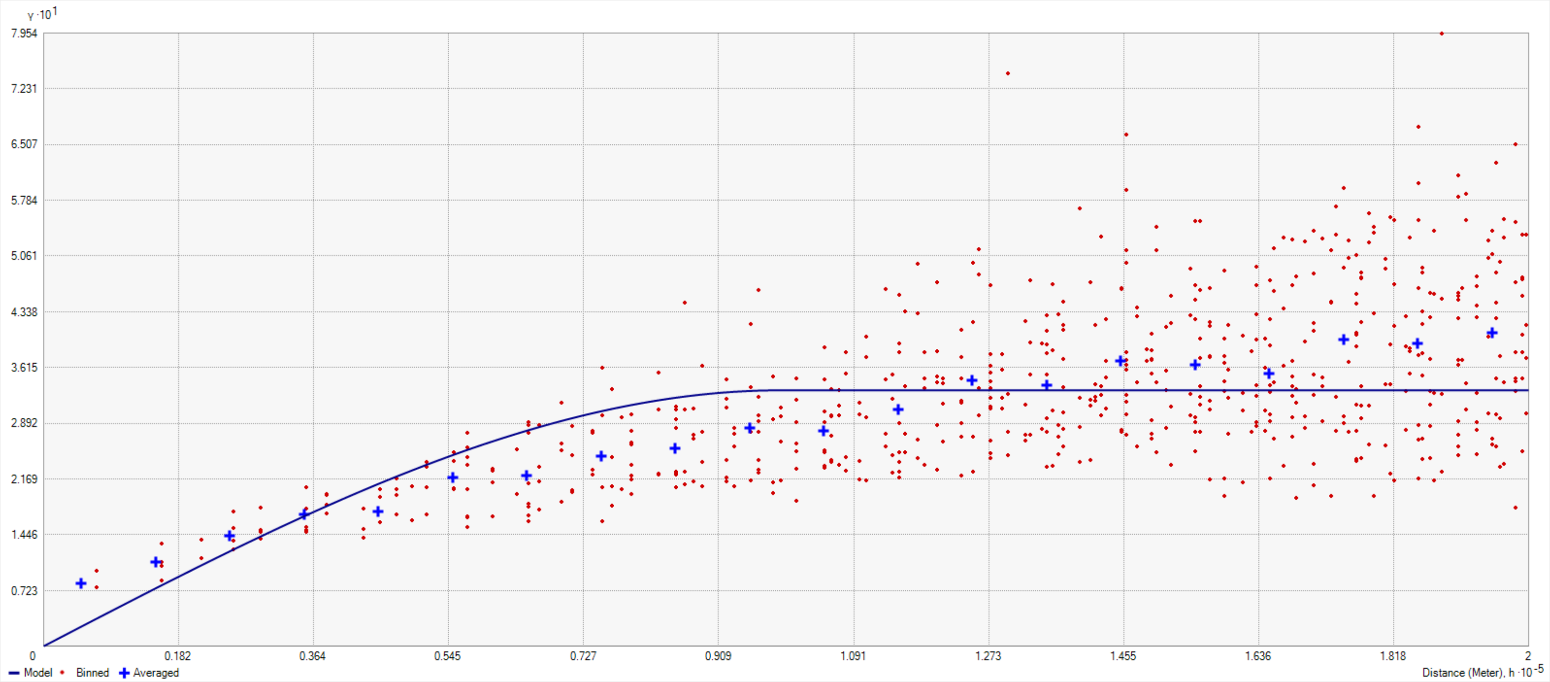
Spatial covariance!

$$\hat{\gamma}(h) = \frac{1}{2N(\boldsymbol{h})} \sum_{(j,i)h_{ij} \in N(\boldsymbol{h})}^{n} \left| x_i - x_j \right|^2$$

Spatial covariance
Long term monthly mean (normal)



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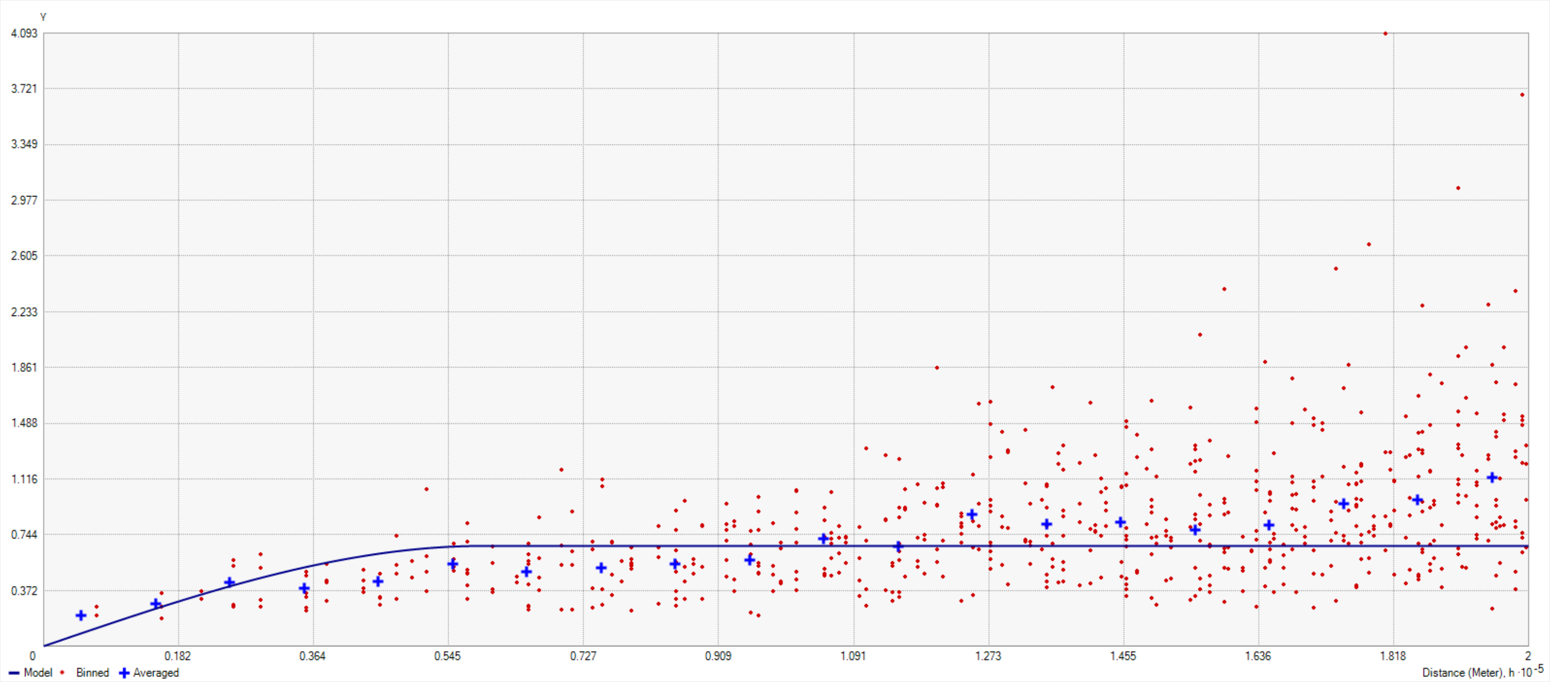
Spatial covariance
Monthly mean



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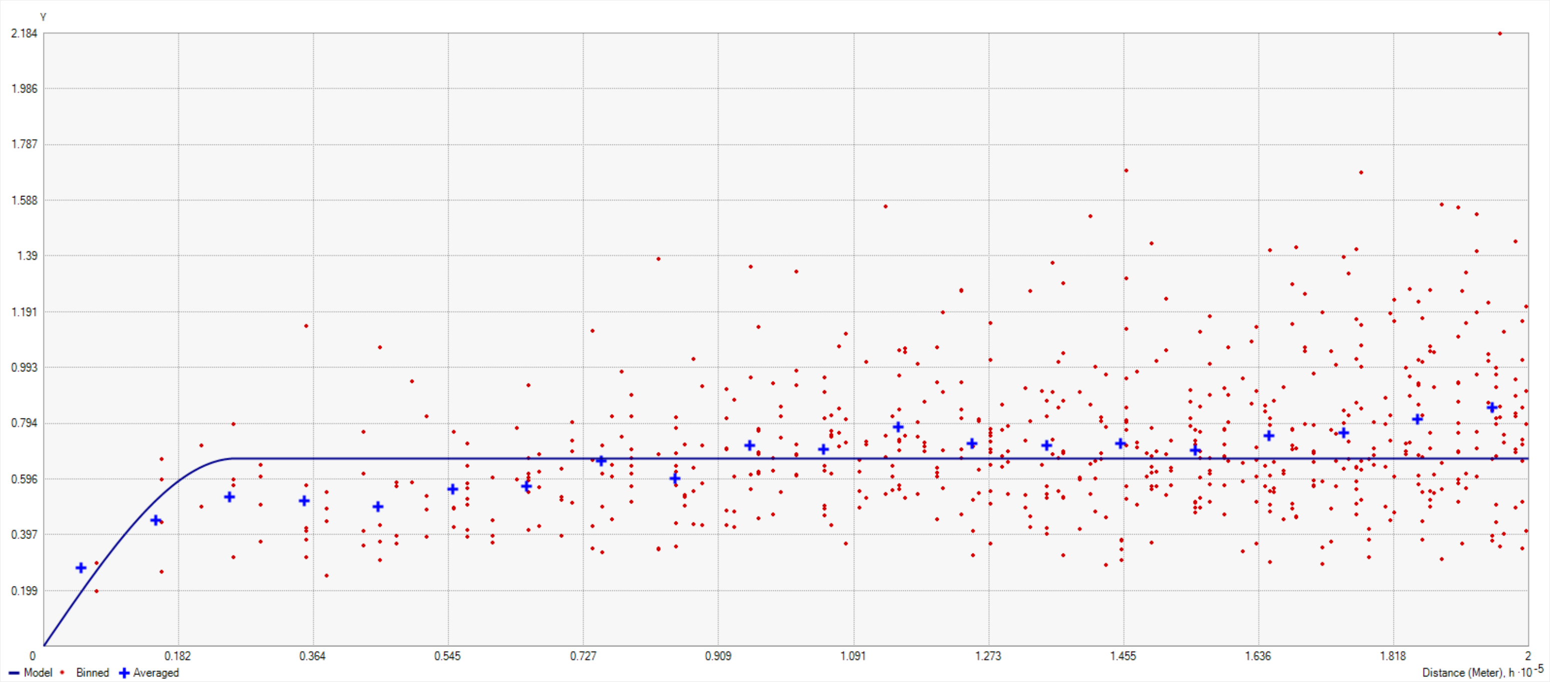
Spatial covariance
Daily mean



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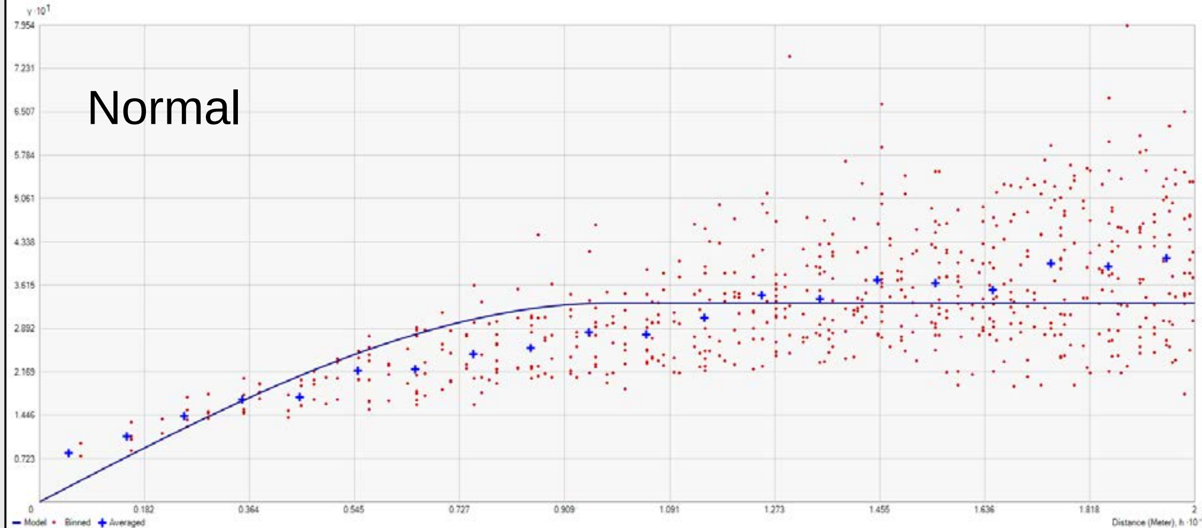
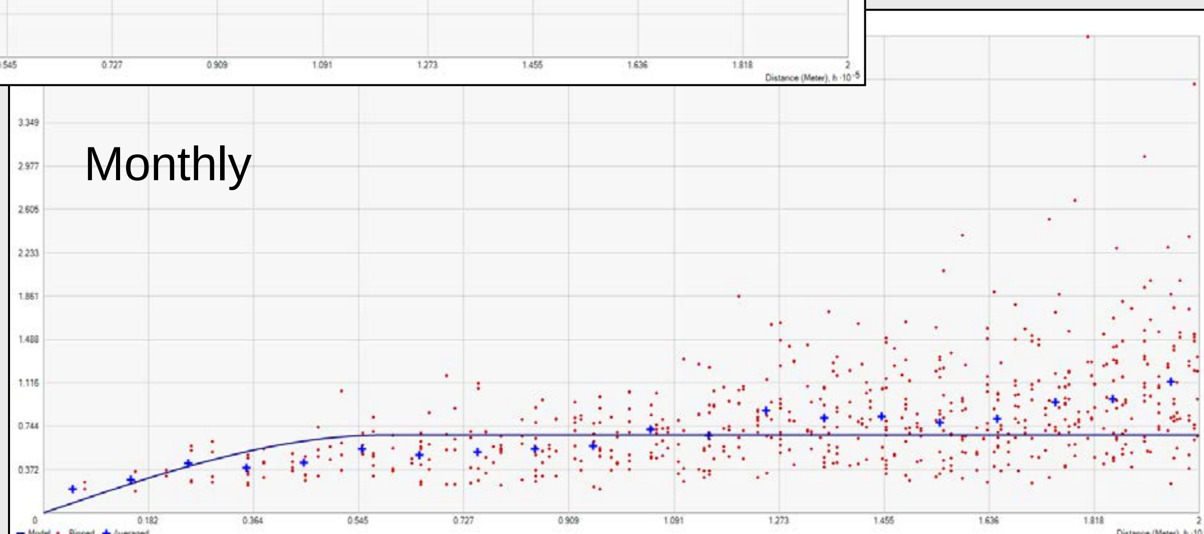
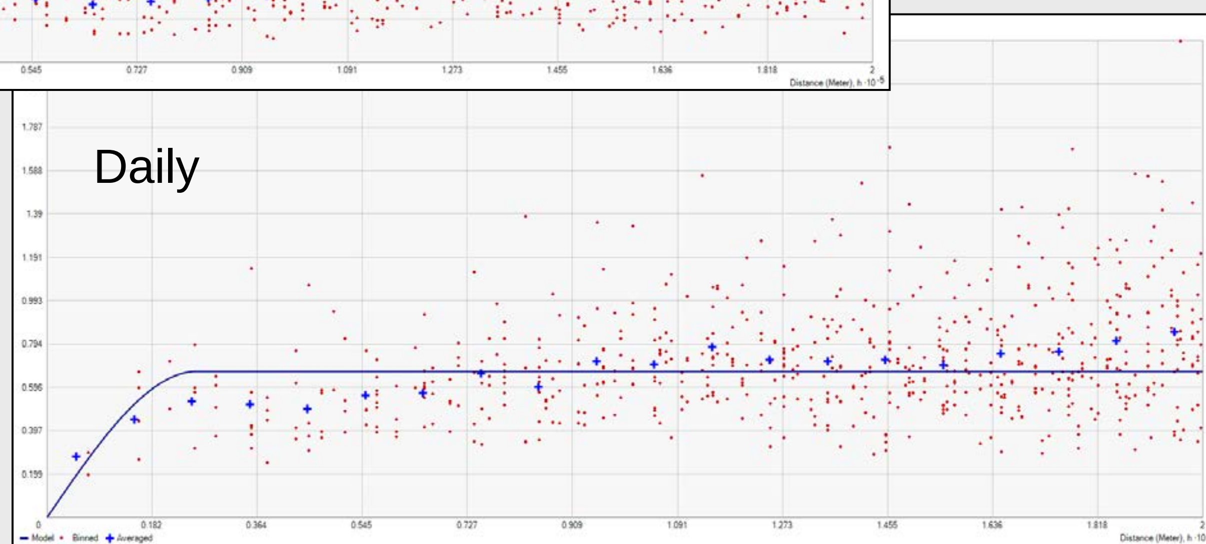
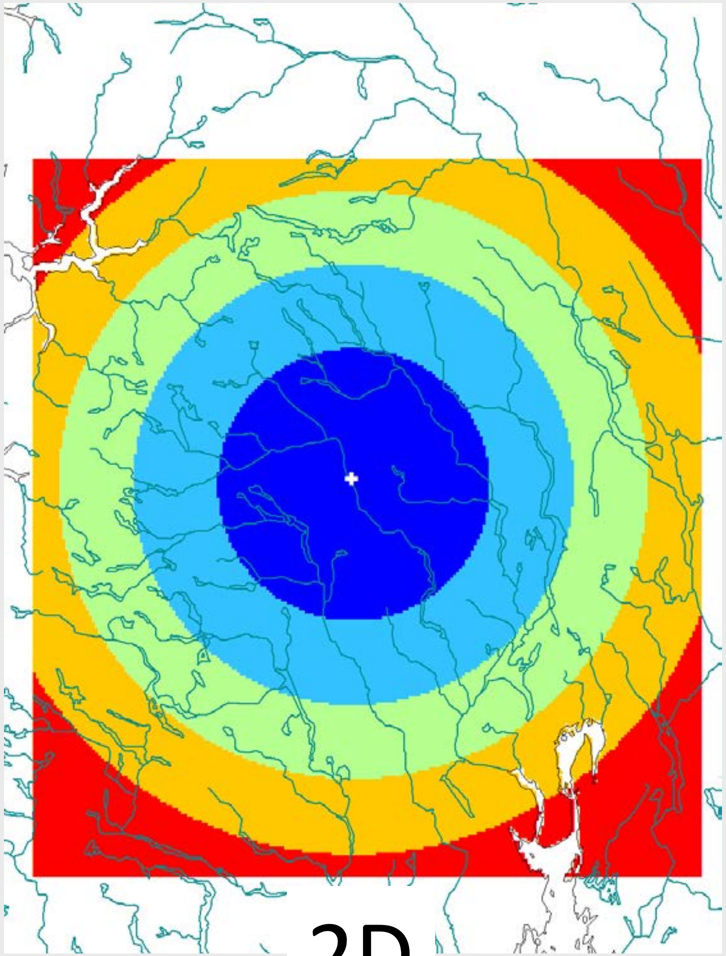

Normal


Monthly


Daily

Distances – Euclidean?



2D

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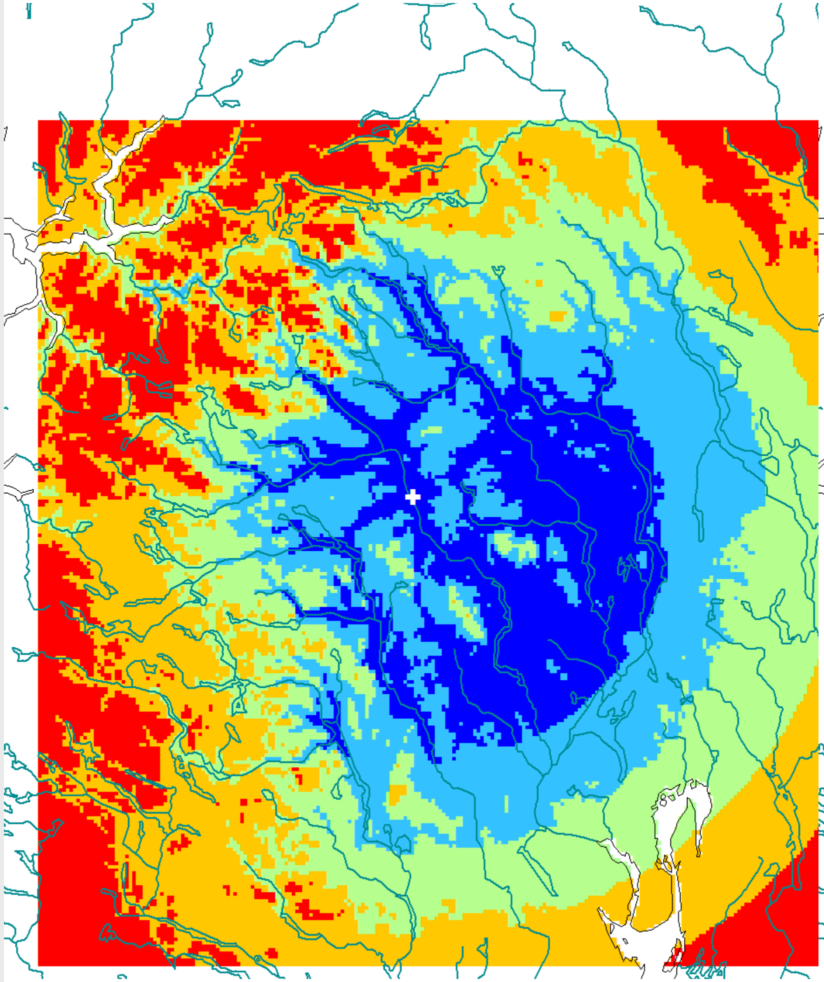
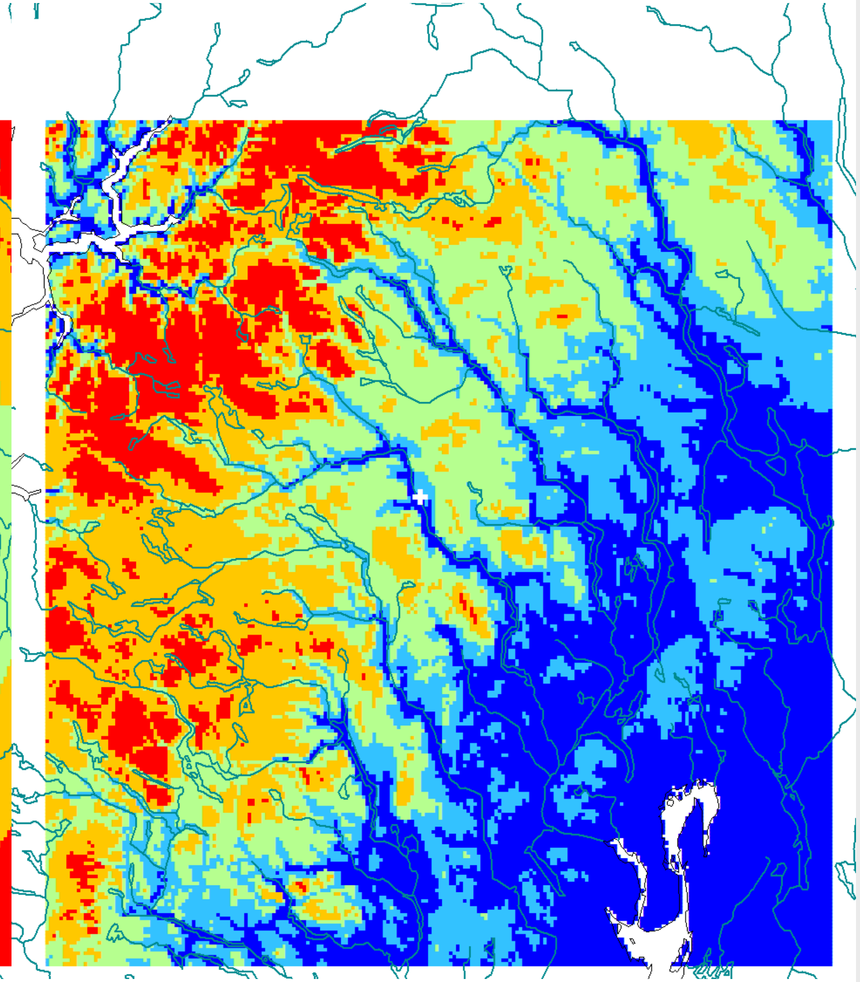
Distances – multi-dimensional



3D 10 m vertical = 1 km horizontal



3D 1 m vertical = 1 km horizontal

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Concept

- Include e.g. elevation in the distance function → 3D distance.
  - →Put stations at same (elevation) level closer to each other.

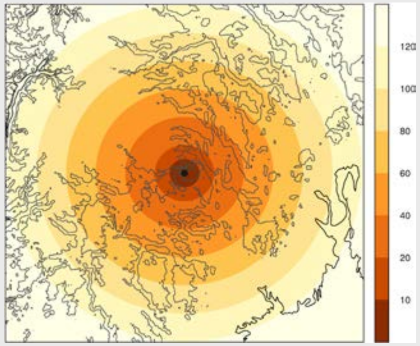
- Include a elevation coefficient; k_z
  - Weight the impact of elevation differences
  - May vary in time and space

$$h = \sqrt{x^2 + y^2 + (k_z \cdot z)^2}$$

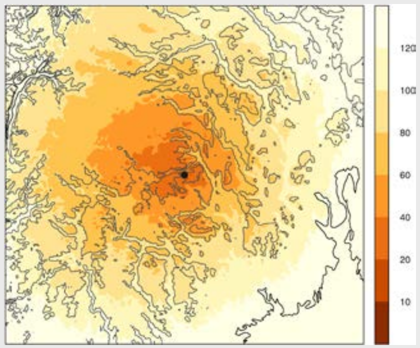
  - Different k's are applied (λ's in examples from Switzerland) based on a priori first guess choices and a c-v selection of the best fit. (OI approach).

- Could be further extended to include anisotropy and more location dependent parameters:

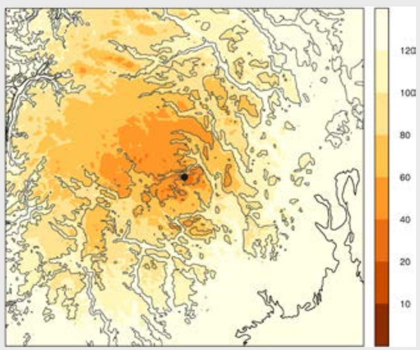
$$h = \sqrt{ax^2 + by^2 + \sum_{i=1}^{n} (\kappa_i Z_i)^2}$$



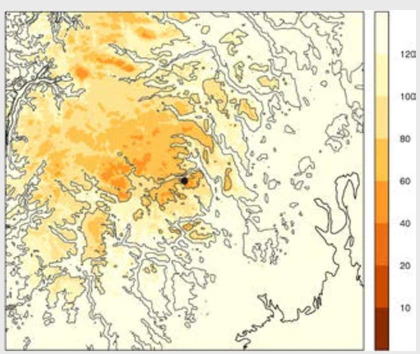
$\lambda=0$



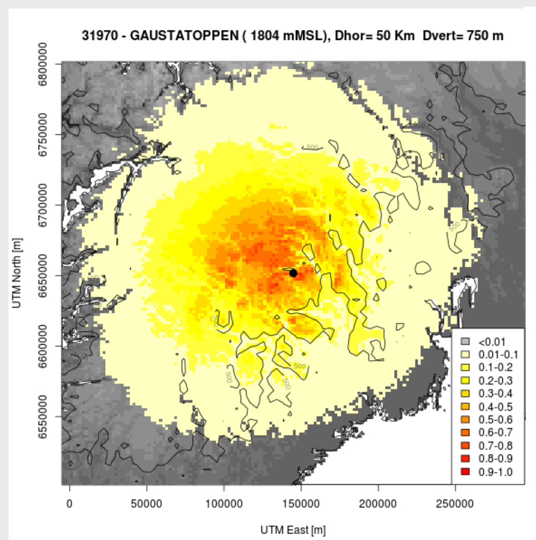
$\lambda=50$

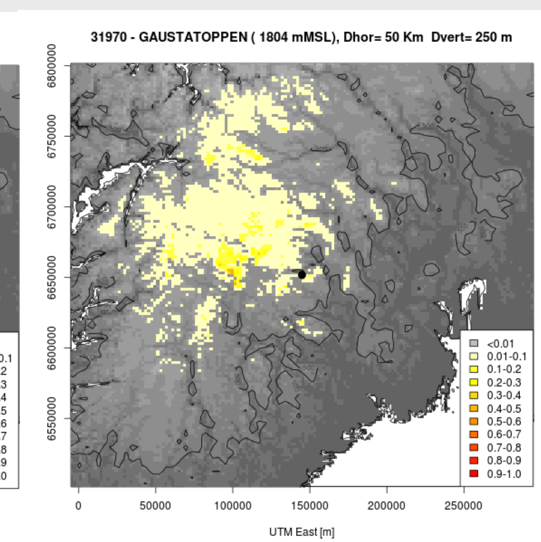


$\lambda=100$



$\lambda=200$

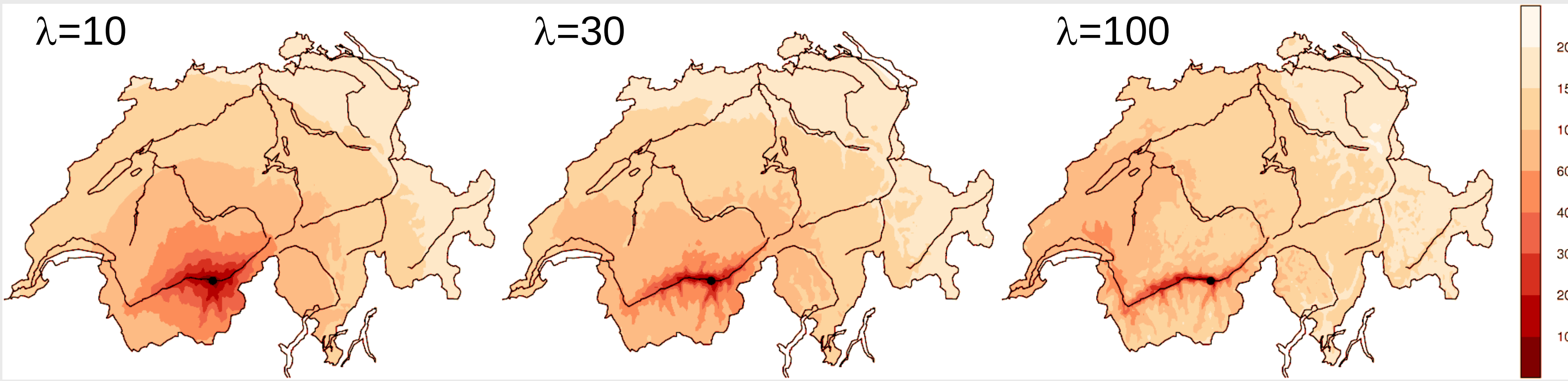




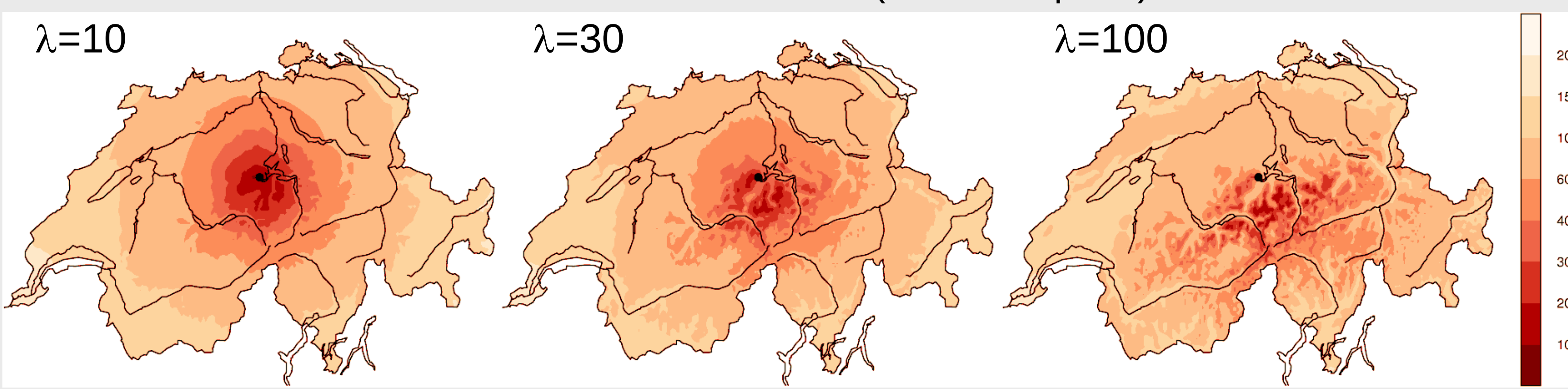
Institute

Non-Eucledian Spatial Representativity

Distance from Visp in km (valley-floor)



Distance from Pilatus in km (mountain peak)



Courtesy of Christoph Frei (Frei 2014 (Int. J. Climatol.))

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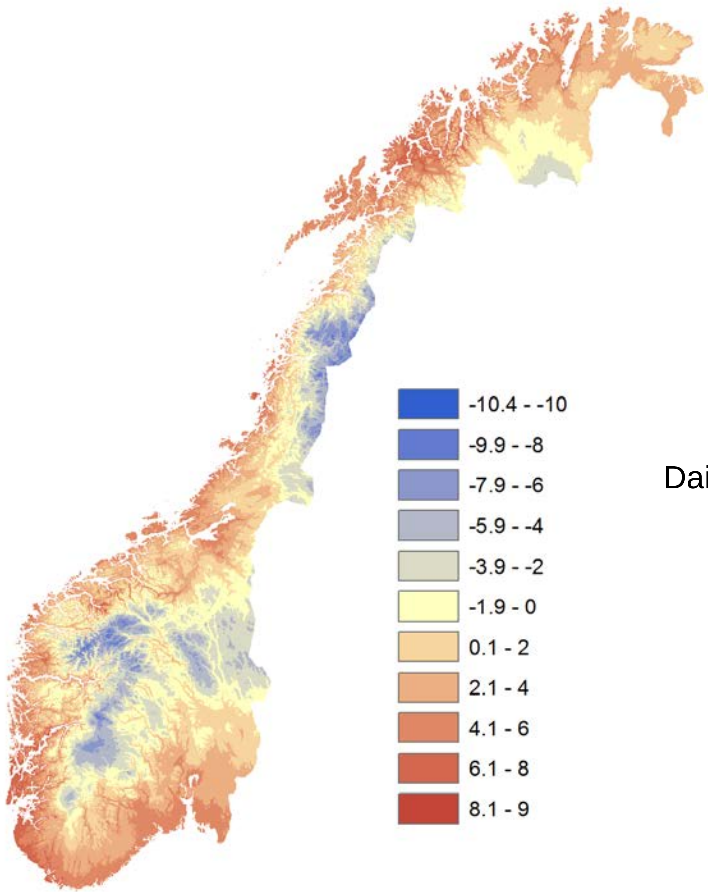
Operational observation gridding in Norway

Daily mean temperature 16.March 2015

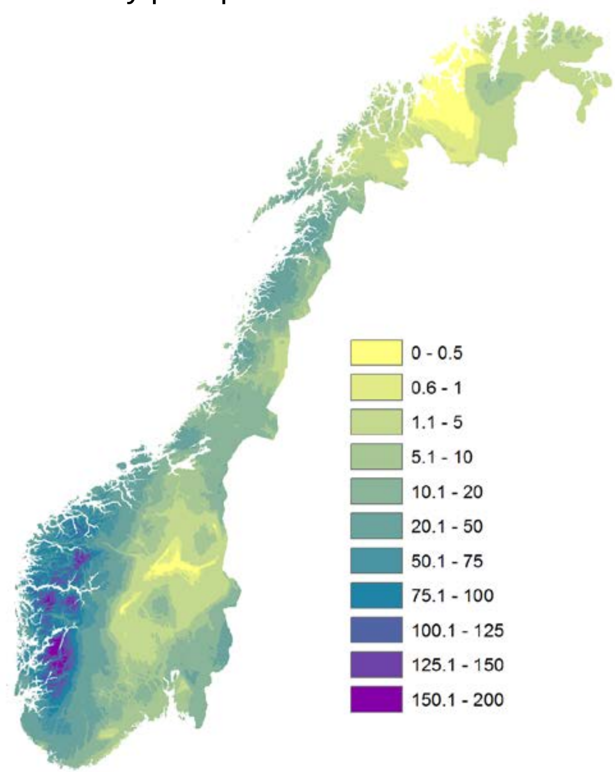


Klimagrid 1.1

Temperature and precipitation

- Period: 01.01.1957 – present
- Resolution: 1x1 km
- Cover mainland Norway.

Daily precipitation 29.October 2014



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Klimagrid v1.1 Temperature

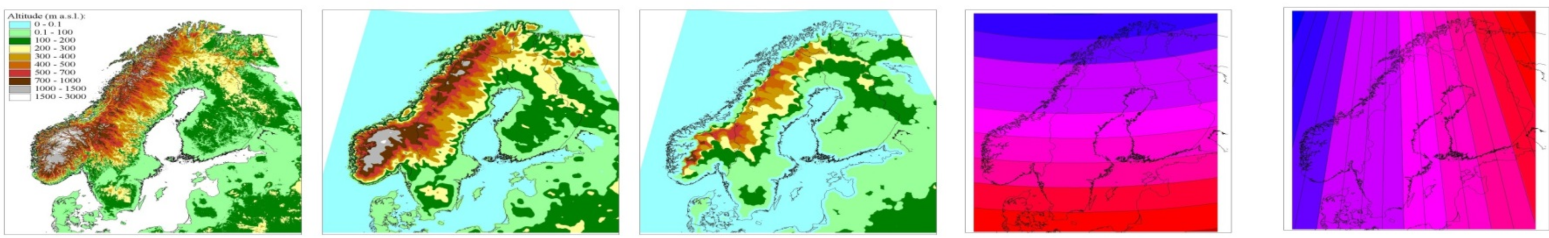
Residual interpolation:

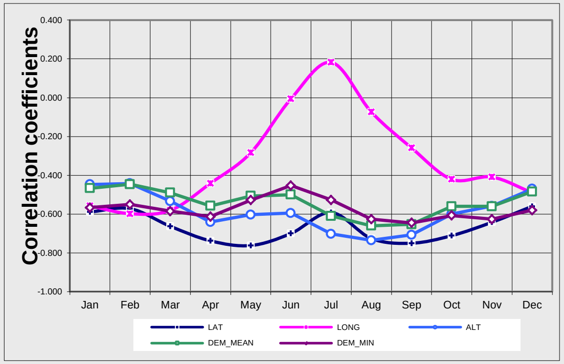
Kriging
(or any spatial interpolation method)

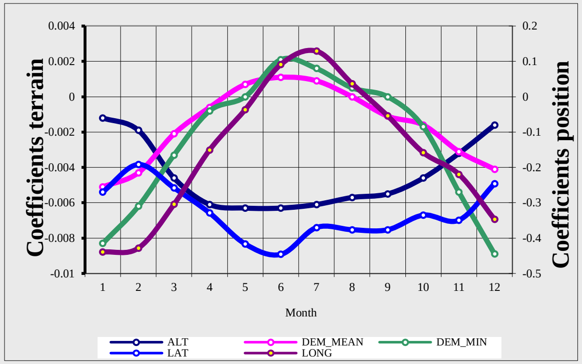
$$\hat{t}(u_0)=\sum_{i=1}^{n}\lambda_i t(u_i)+\{\alpha_0+\alpha_1\beta_1(u_0)+\alpha_2\beta_2(u_0)+........+\alpha_m\beta_m(u_0)\}$$

External trend/drift
(linear regression)

Predictor fields:







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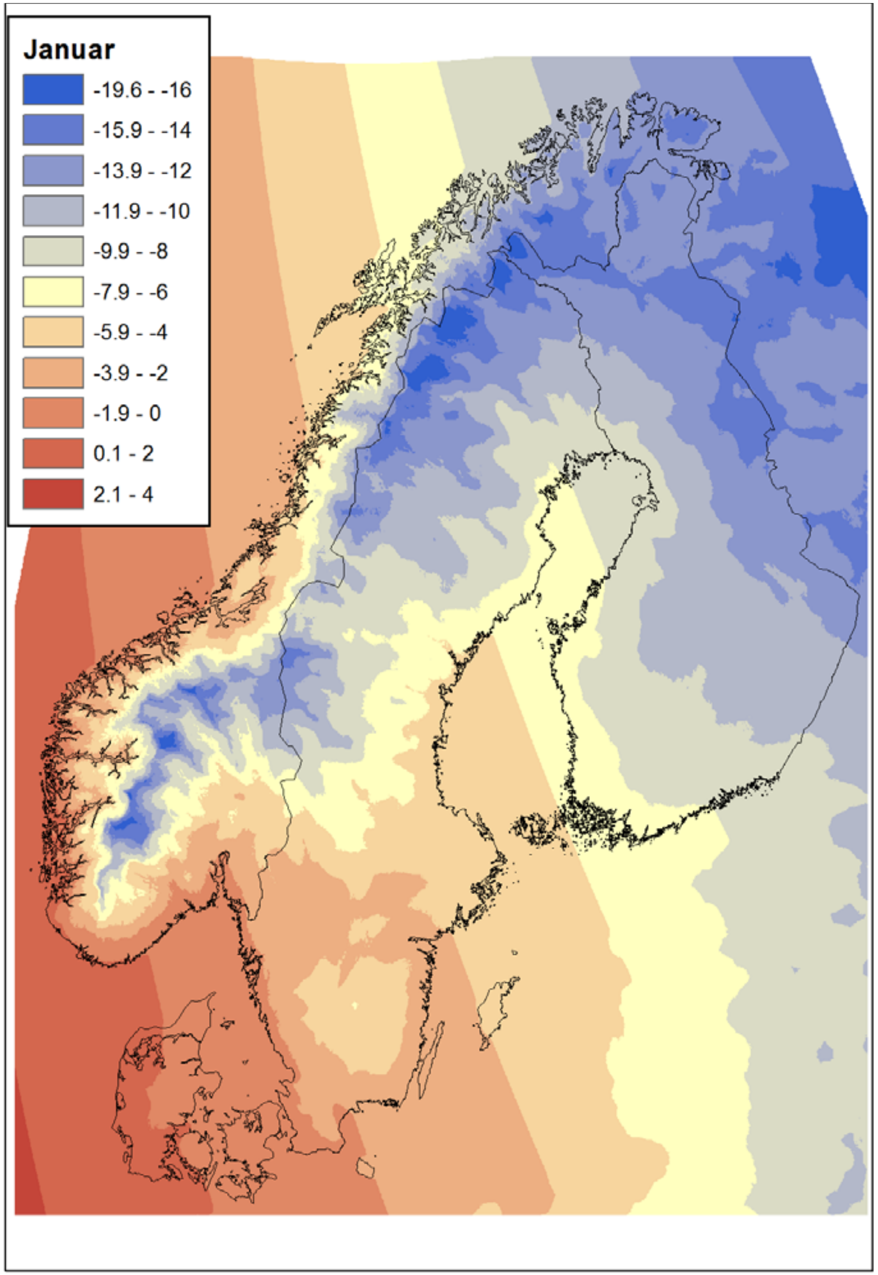
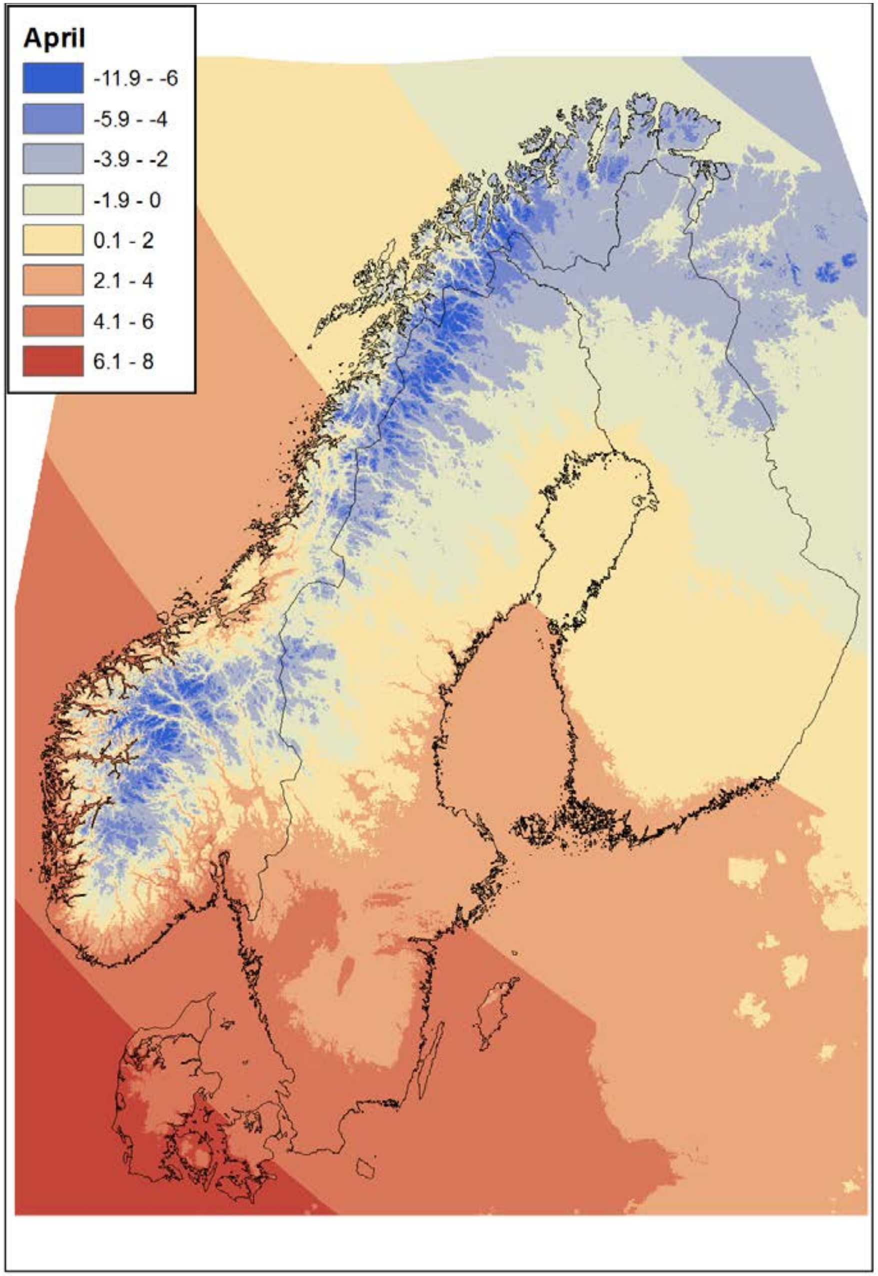
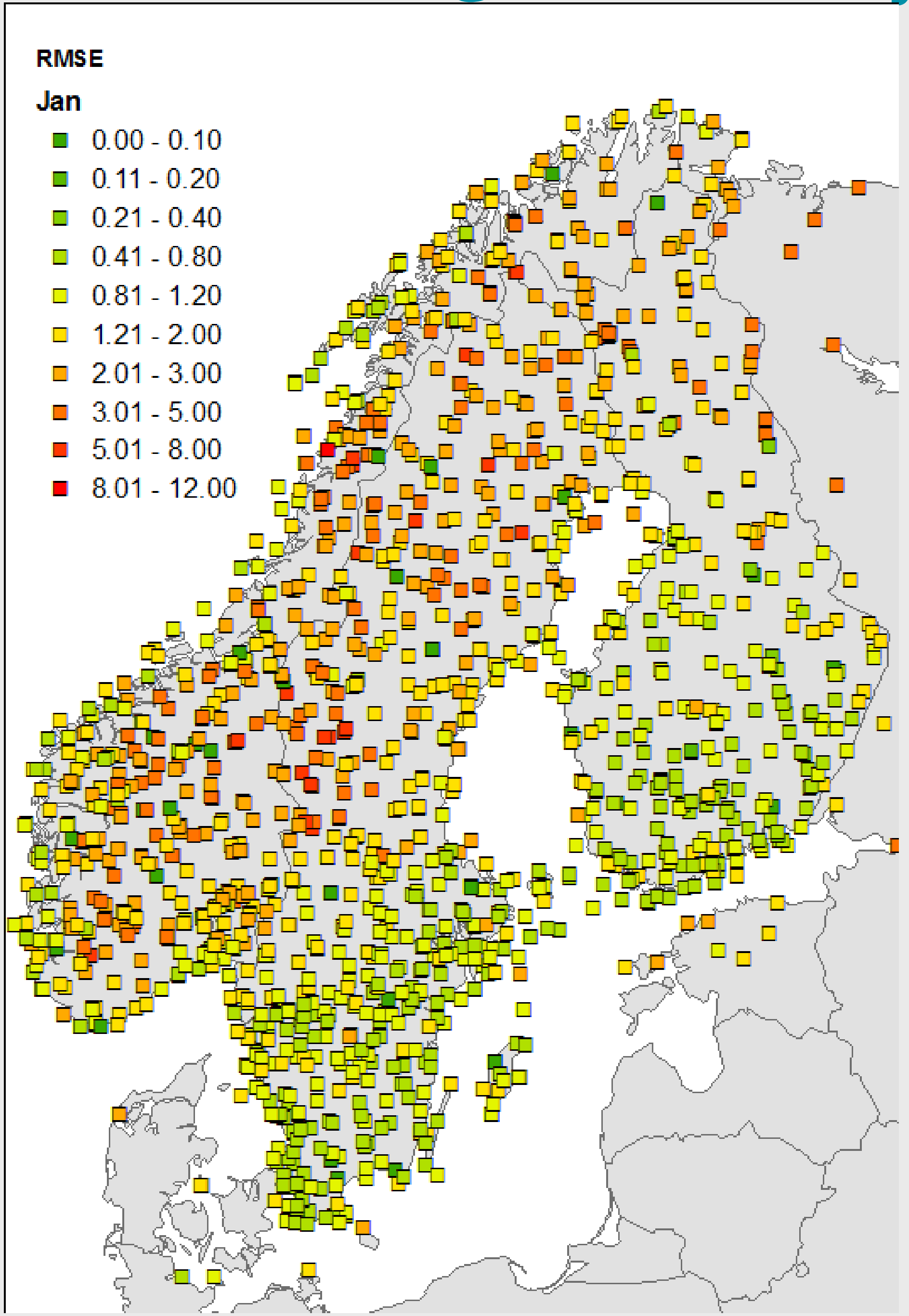
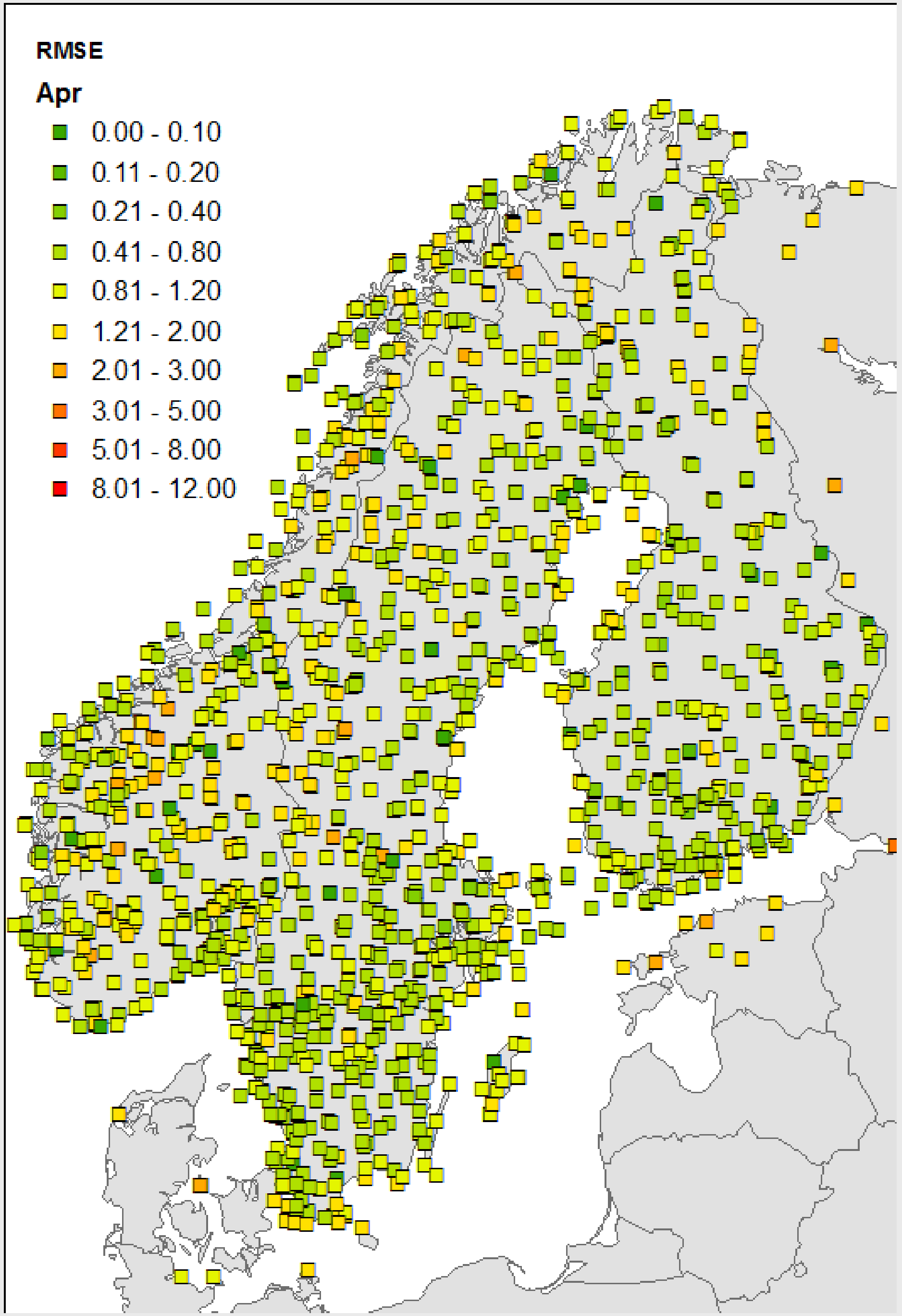
Trend ➔ climatological first guess (monthly)





NGCD.RK @ MET Norway – TEMP1d - Evaluation





Klimagrid v 2.0

- **Replace** the current Klimagrid1.1 (SeNorge1.1)
- **seNorge:** gridded datasets; Norwegian mainland +parts of Sweden and Finland; 1Km resolution
- *source:* Observations from MET Norway Climate database (manual + automatic weather station data)

- Precipitation 1h (RR_1)
- Precipitation 3h (based on hourly observations)
- Temperature hourly (TA)

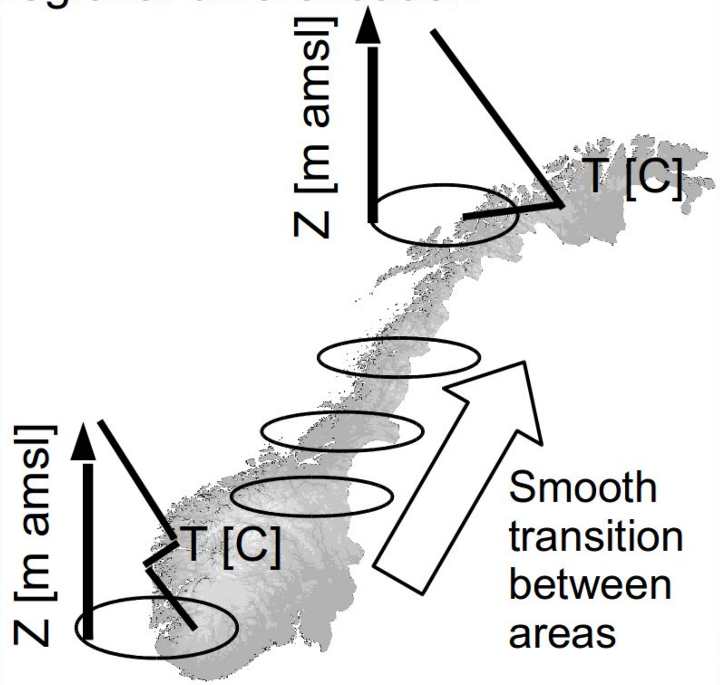
- Precipitation daily (RR)
- Temperature daily mean (TAM)

Periods:
Hourly datasets 2010.01.01 onwards (hourly updated)
Daily datasets 1957.01.01 onwards (updated daily)

Klimagrid 2.0
TEMP1d: OI

Large(coarser) scale trend estimation

Spatial interpolation: Large Scale. nonlinear detrending allowing for regional differentiation



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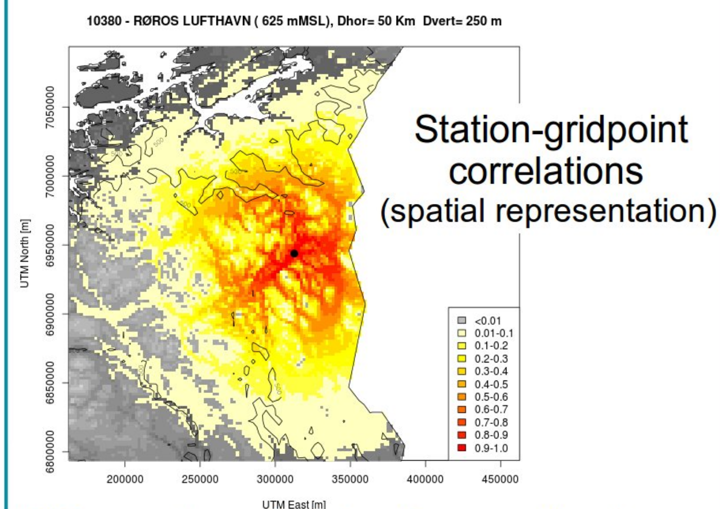
Spatial Interpolation: Small Scale. Correlation functions are defined a priori in the Optimal Interpolation scheme.



Different weights for vertical and horizontal distances.

OI introduces the Local(finer) scale

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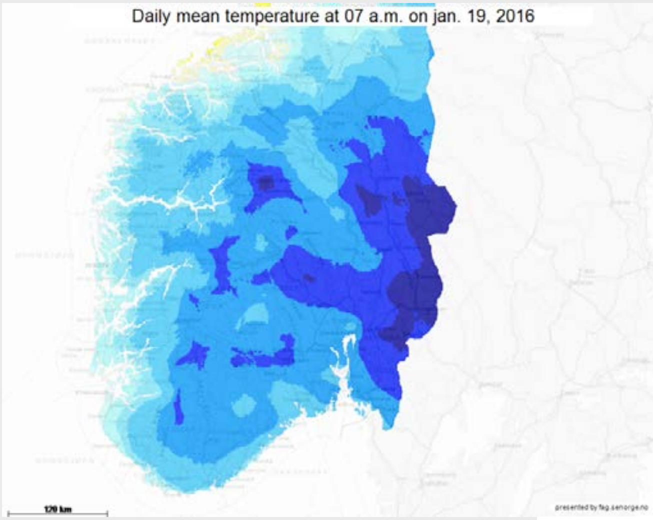
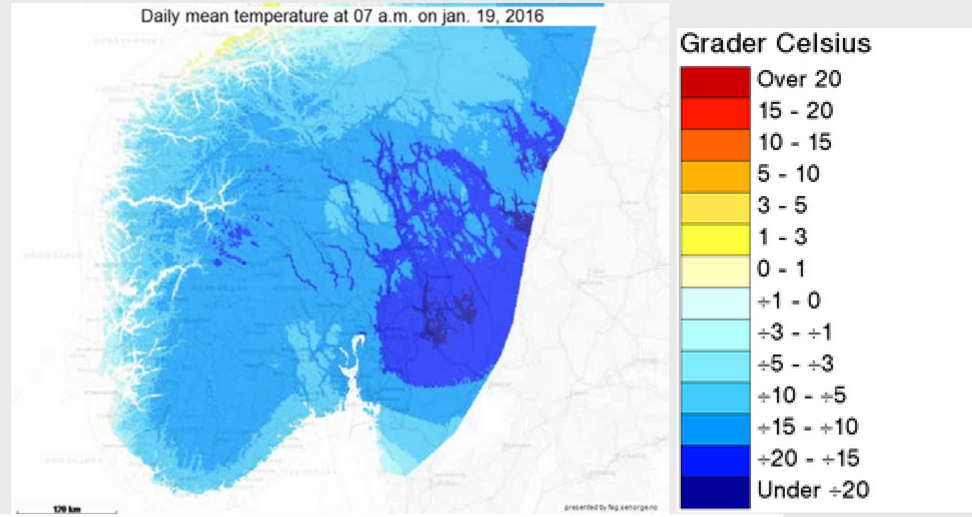
Old method

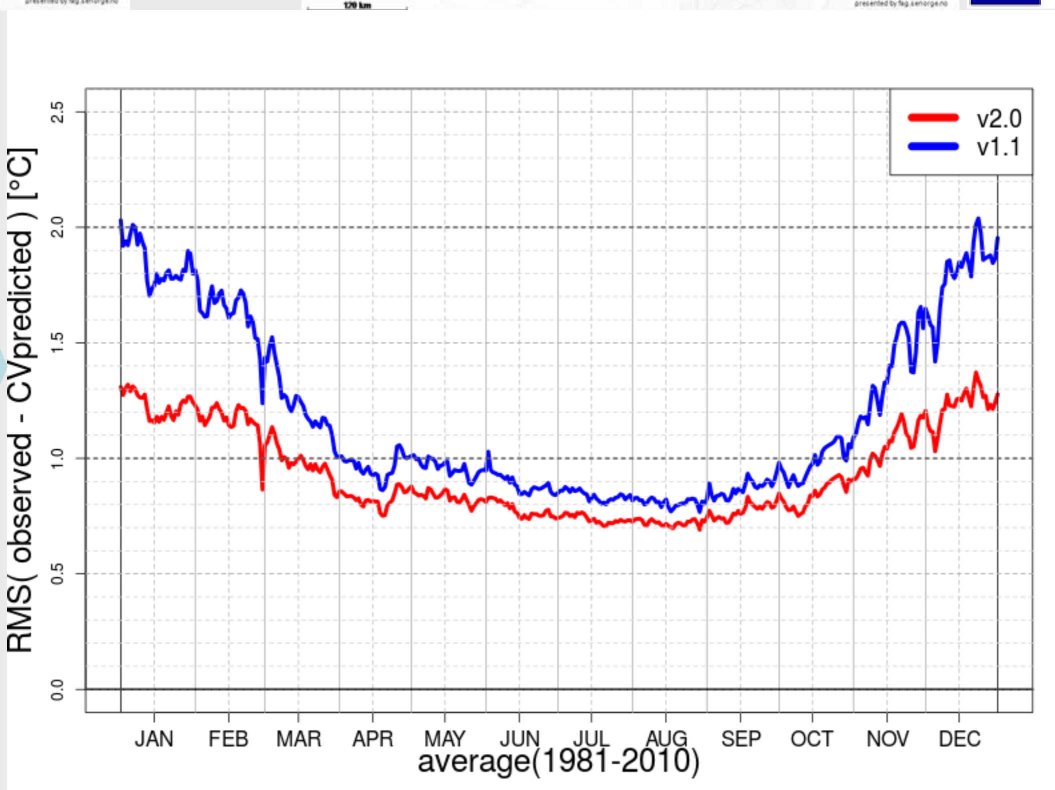


New method



New method reduce estimation error.

(RMSE, independent cross-validation)



Precipitation gridding

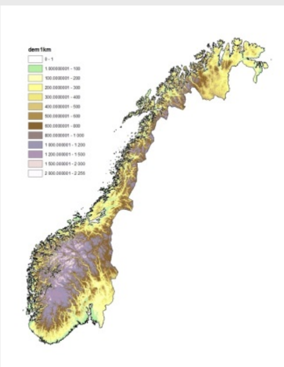
- Non-continuous, in time and space

- Skew distribution, with lower boundary.

- A two-step procedure normally applied:
  - Define areas with precipitation (above a certain threshold) ➔ indicator interpolation.
  - Define precipitation amounts in those grid cells.

Precipitation v1.1

- Triangulation.
- Includes elevation dependence.
- Correction for wind-loss.



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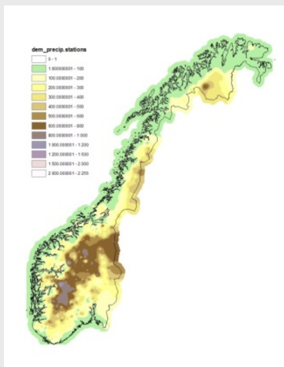

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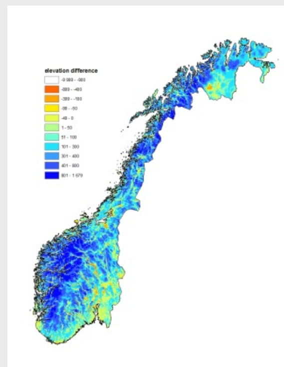

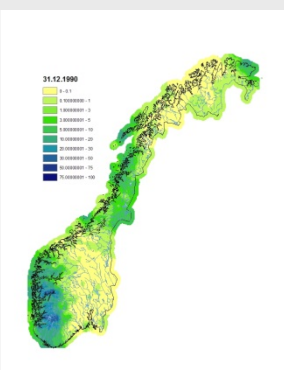

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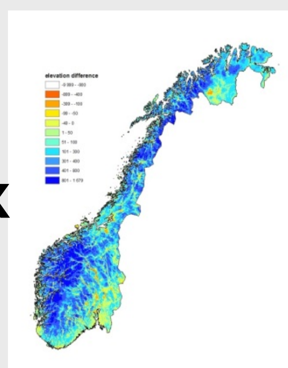

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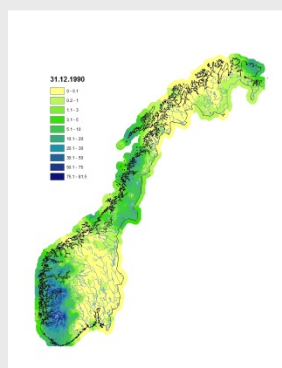

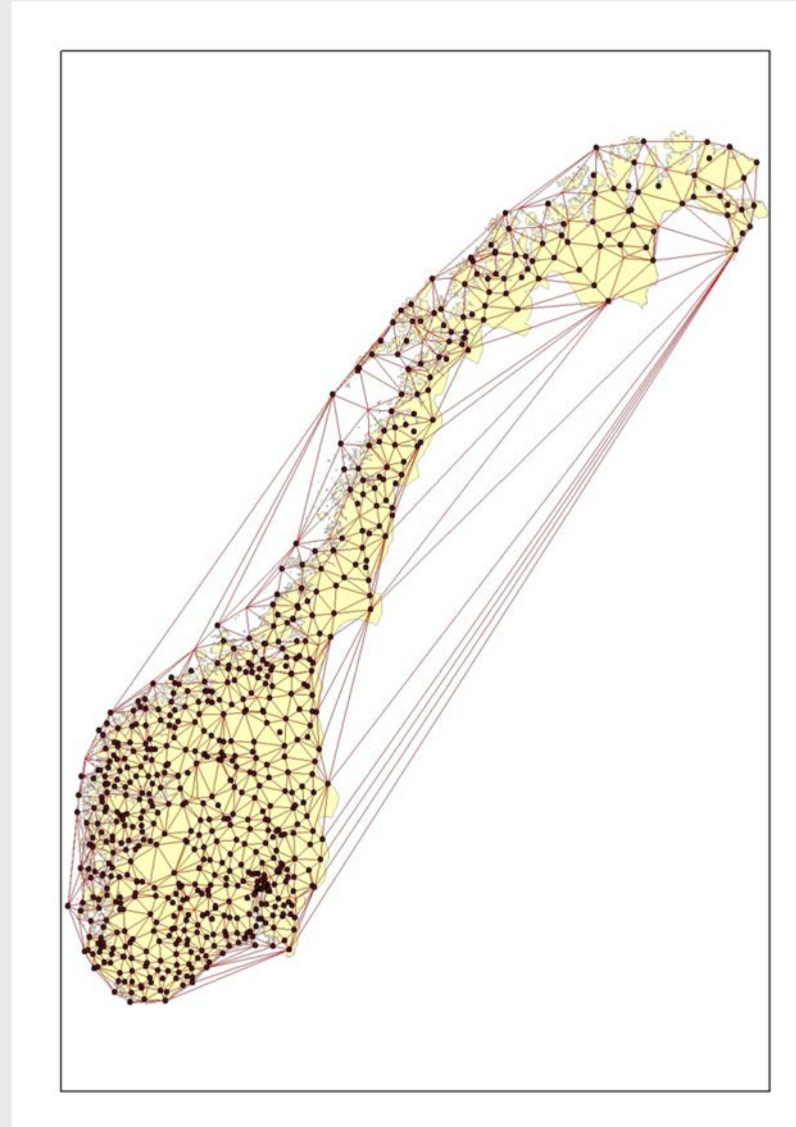

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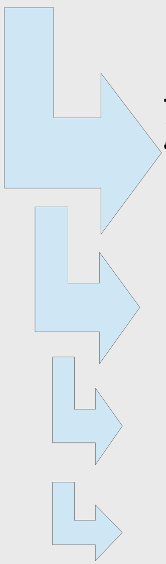
Precip v.2.0 - procedure

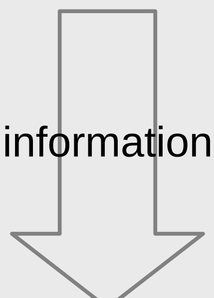
- Identification of Events
  - Precipitation yes/no distinction (gridpoints)
  - Contiguous Precipitation Areas (CPAs) identification and labeling
- Iterative loop over Events
  - Multiscale Optimal Interpolation
    - Event coarser scale



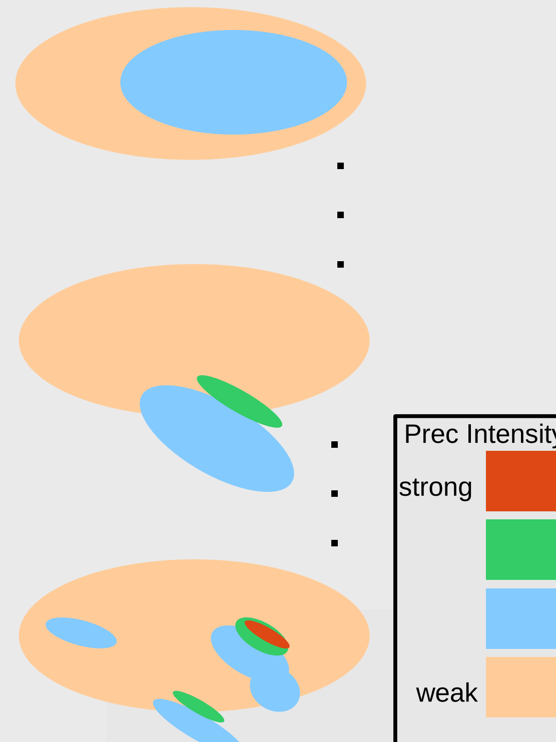
Cascade of spatial scales: from coarser to finer levels

- Event finer scale

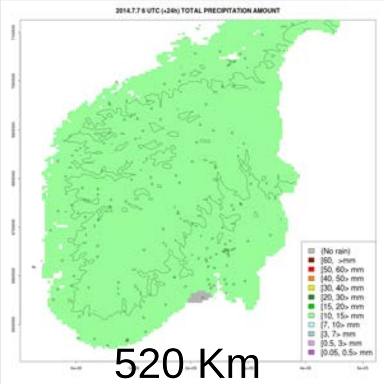
At coarser spatial scales, precipitation events have a less complex (*smoother*) representation.

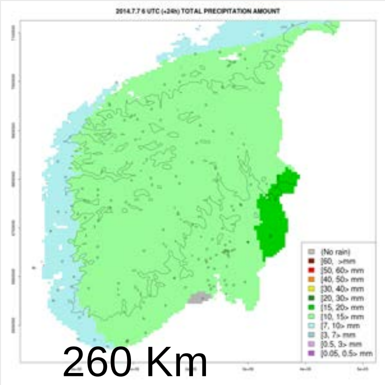


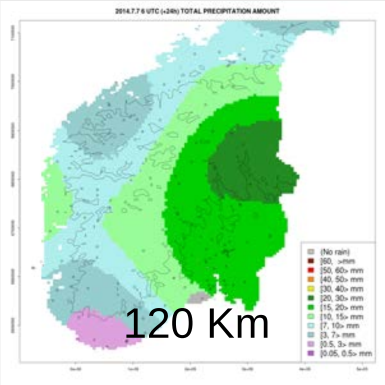
At finer spatial scales, the measured precipitation shows a greater variability.

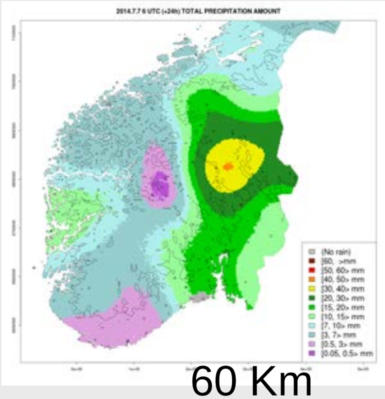


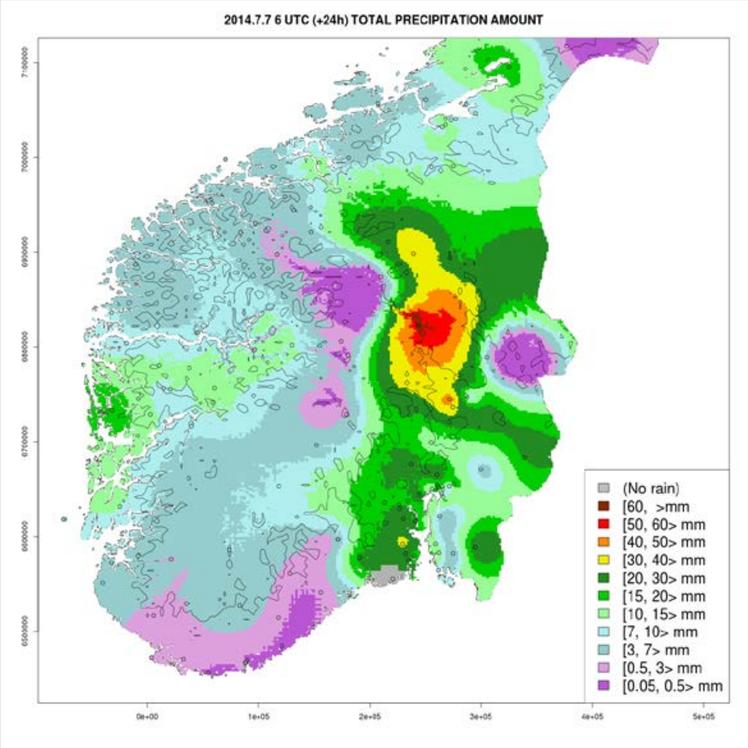
Multiscale modified OI


520 Km


260 Km


120 Km


60 Km



Final result

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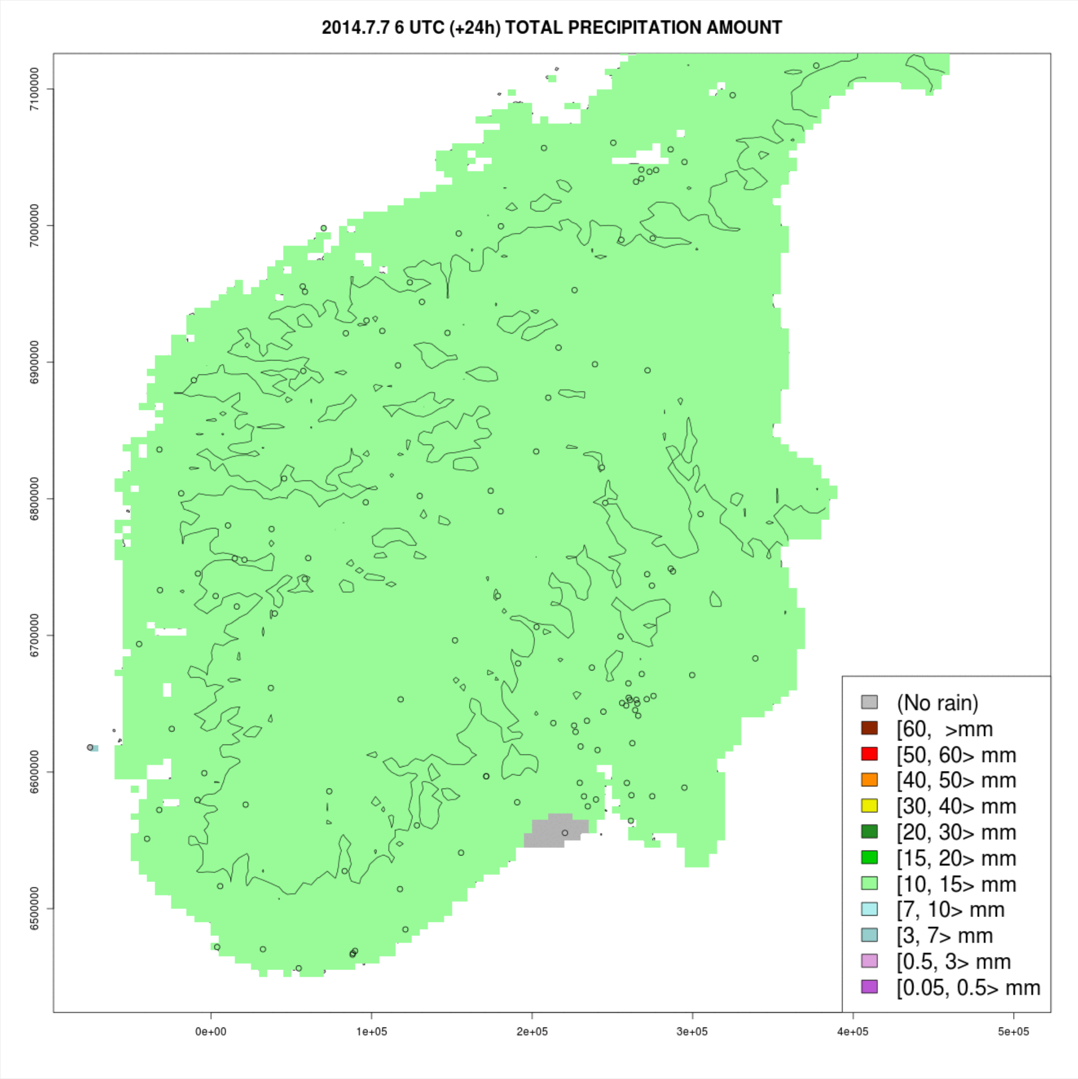
Multiscale modified OI



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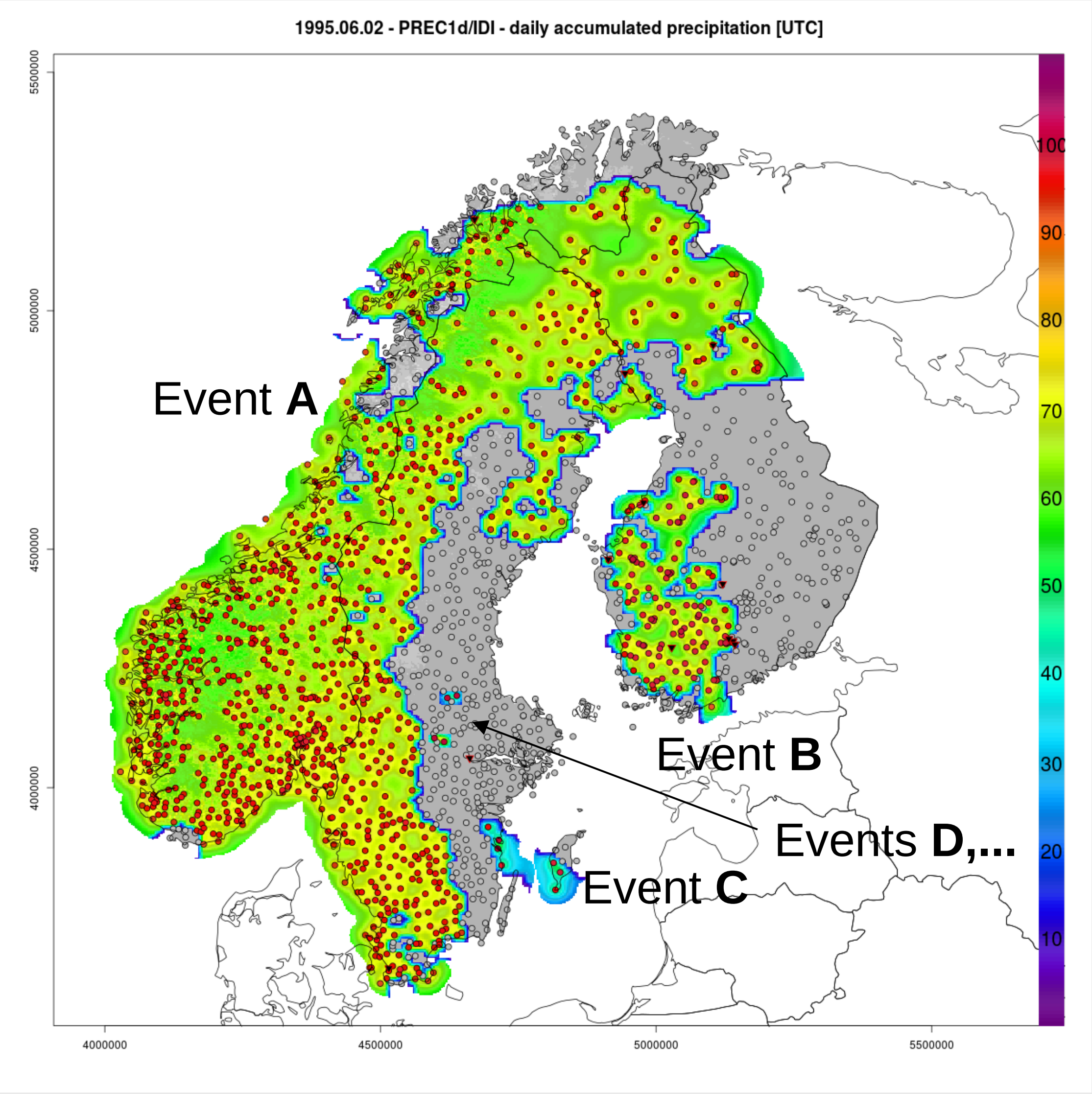
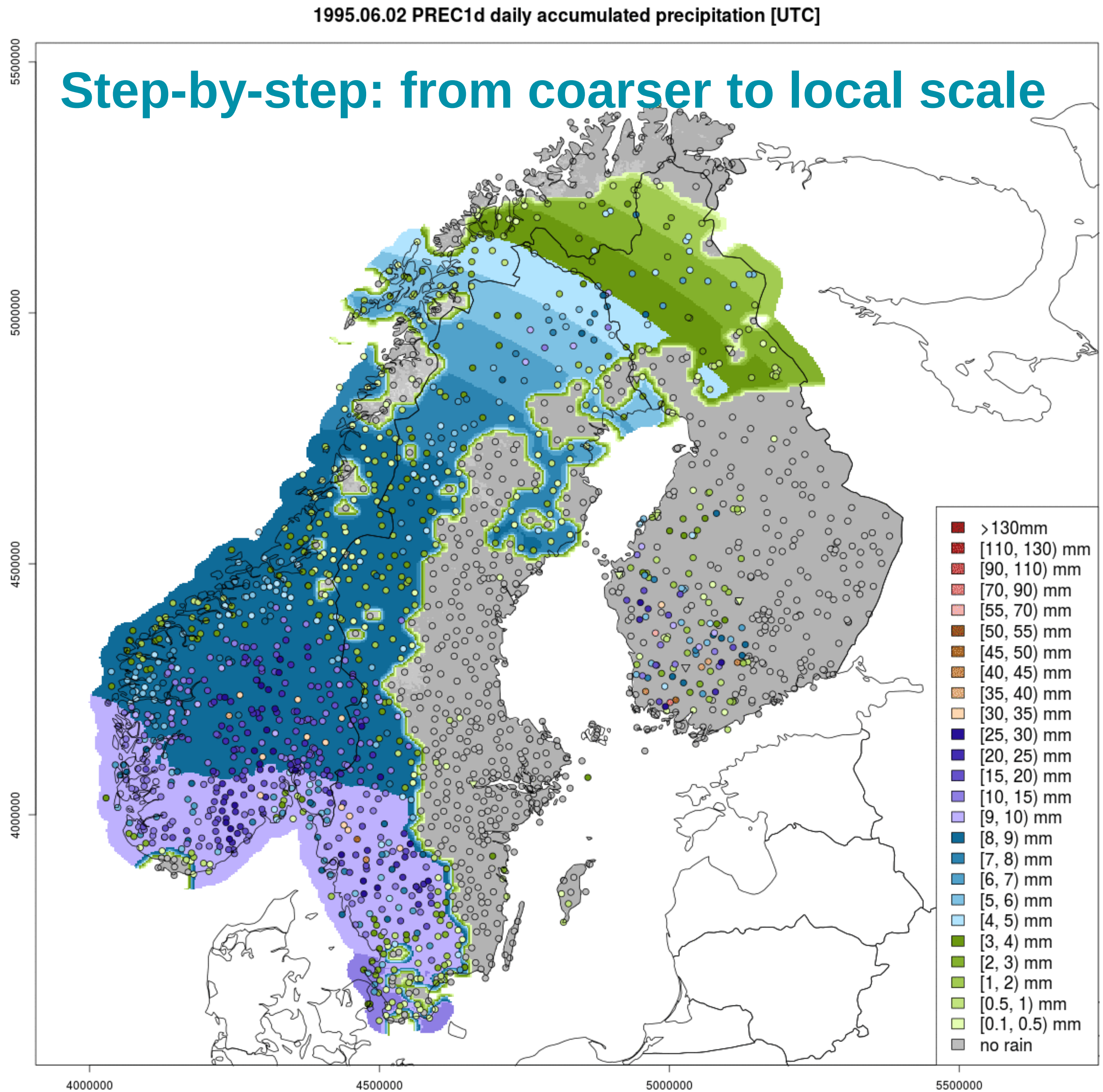
Spatial Interpolation Method based on Multi-scale Optimal Interpolation (Prec)

<u>Step 0:</u> <u>Identification of Precipitation Events (Observed Areas of Precipitation)</u>
(given the Station distribution)



Multi-Scale Optimal Interpolation

Step-by-step: from coarser to local scale



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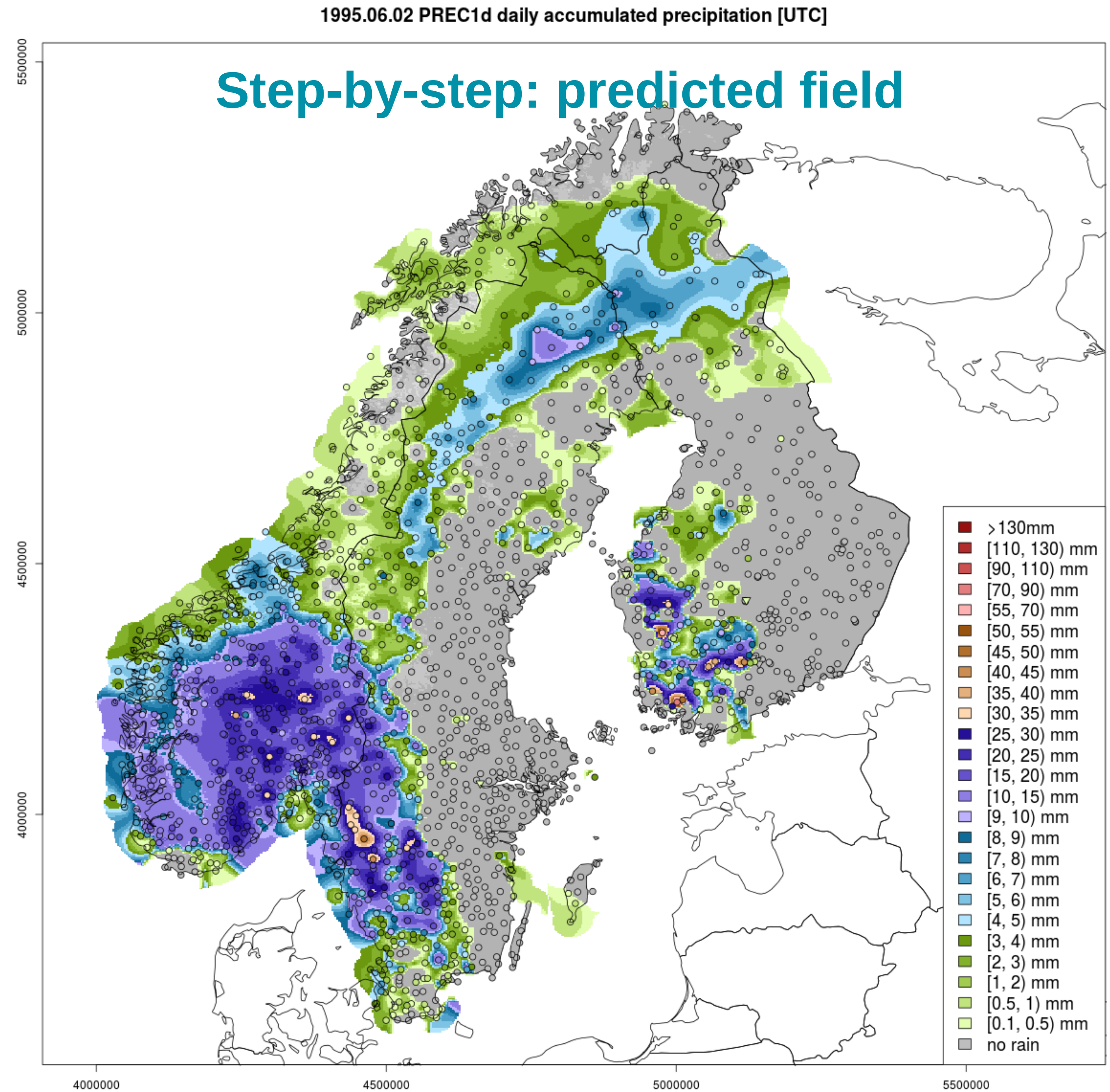
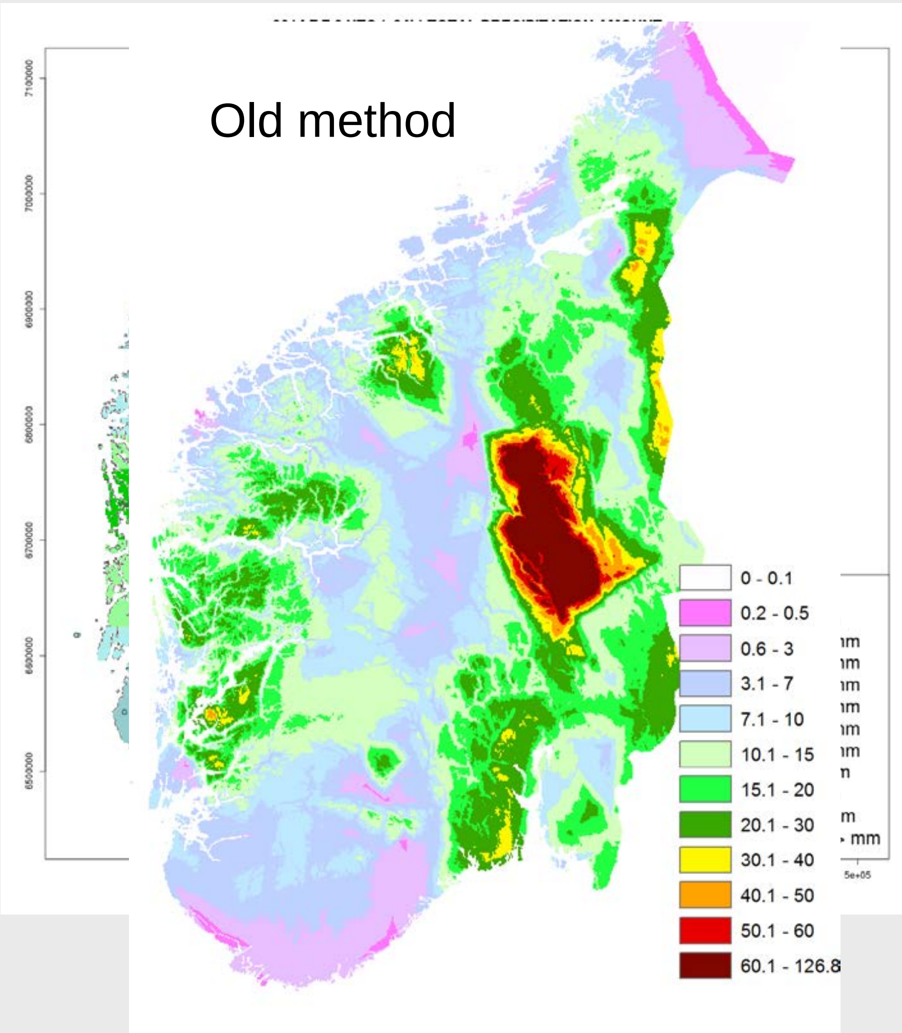
Multi-Scale Optimal Interpolation

Step-by-step: predicted field

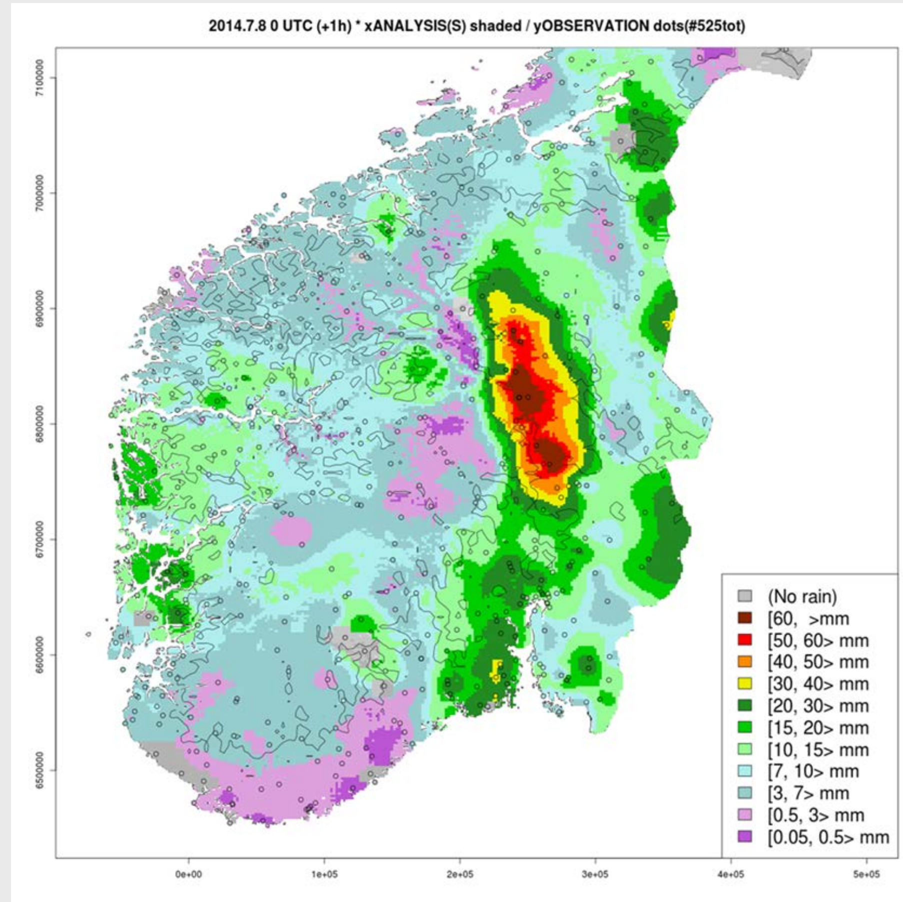


The importance of Station density

150 stations, 1h precipitation,
(Figure shows 24h Prec)



525 stations, daily precipitation



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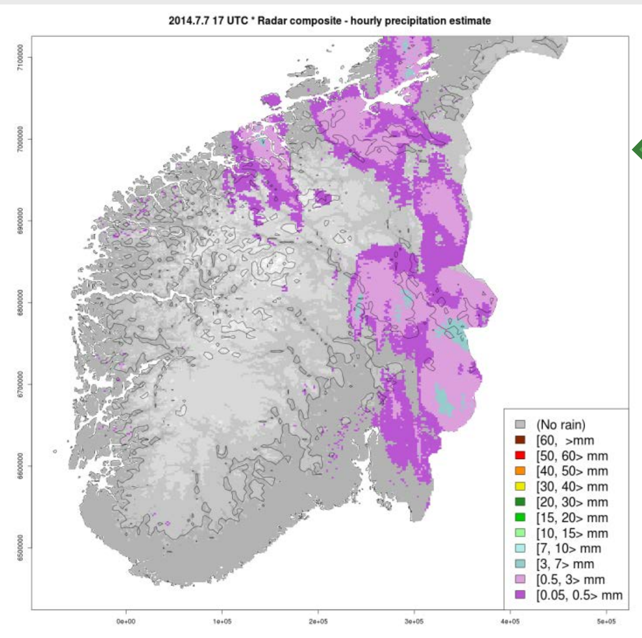
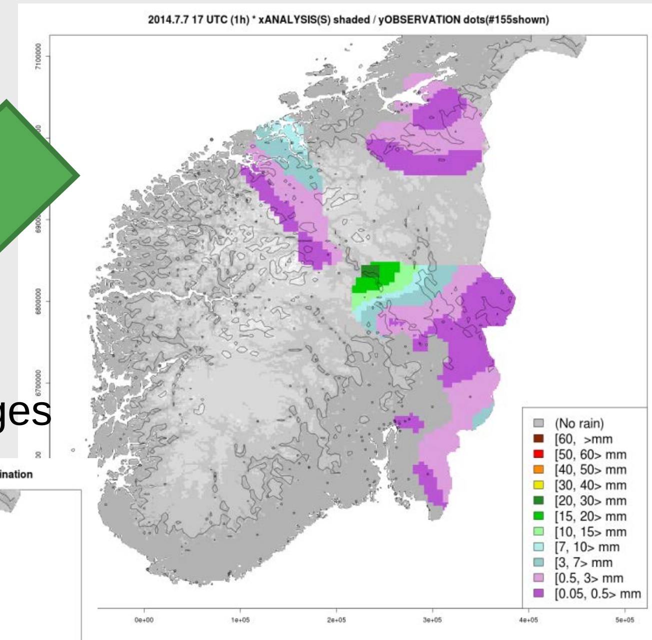
Convective rainstorm in Norway (7.July 2014)

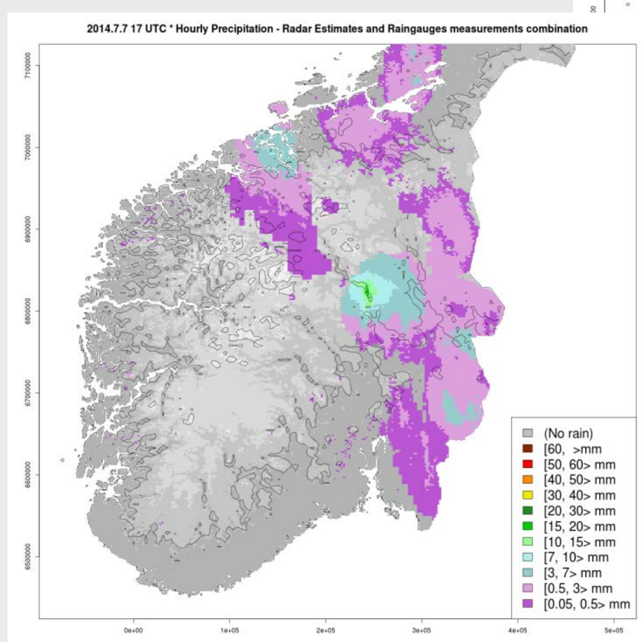
Radar



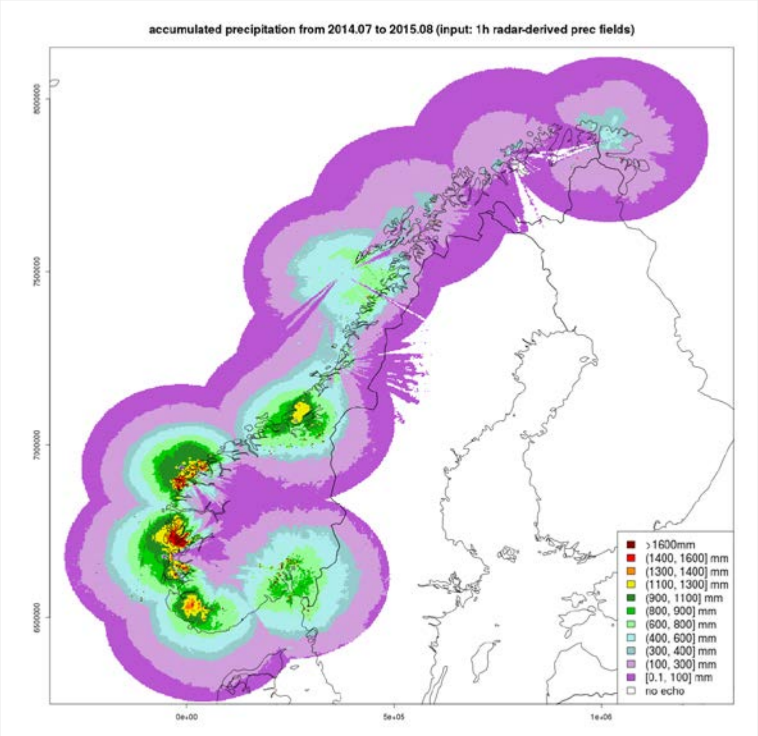
Automatic weather stations



Combination radar+raingauges



Gridding challenges



- Daily
- Hourly
  - Sub-hourly needed for city planning

- Combine datasources
  - In-situ observations
  - Radar
  - Satellite data
  - Model fields (NWP, RA)

- Ensemble gridding/Uncertainty assessment
  - Conditional stochastic simulations
  - Bayesian statistical analysis (OI) in «an ensemble» mode
  - Analogue techniques

  - Atm. circulation as conditional input?’
  - Observations itself set the conditions?

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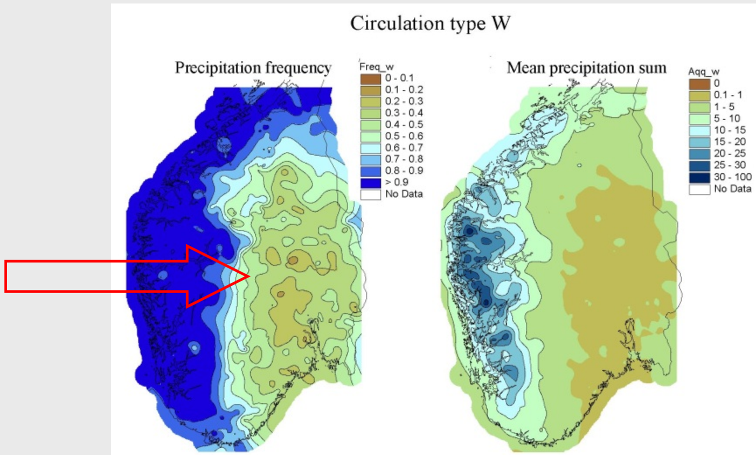
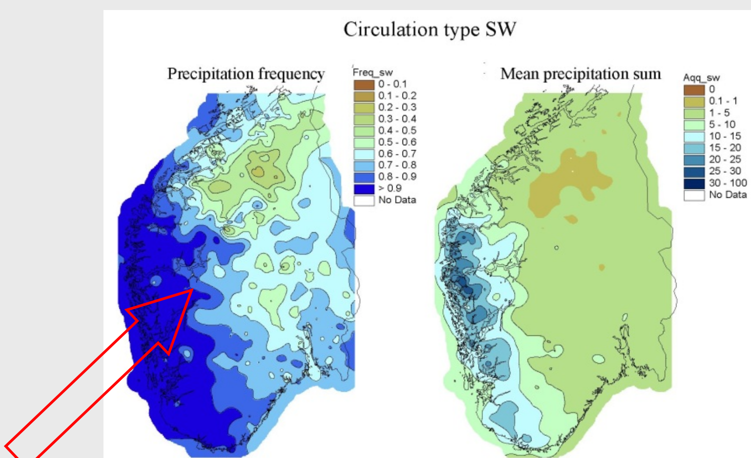
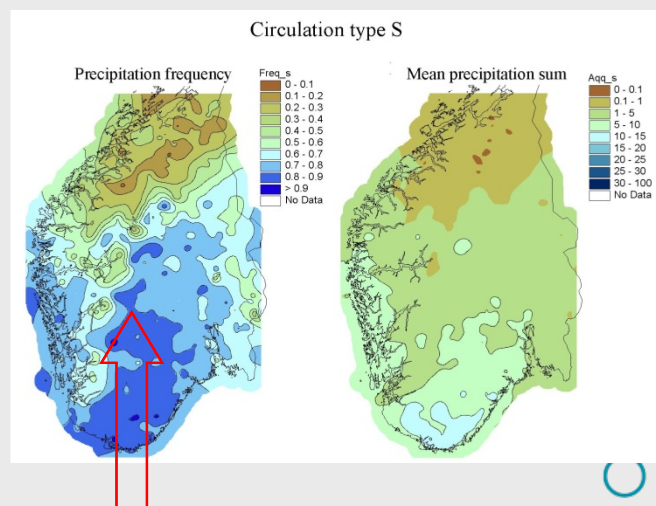
Atmospheric circulation & precipitation



Precipitation distribution depends on the circulation, and small changes in the atm. circulation will have large impact on the precipitation patterns.

Weather types/circulation indices can therefore be used to give conditional parameterisation of spatial interpolation algorithms of precipitation as well as temperature and other climatic elements.





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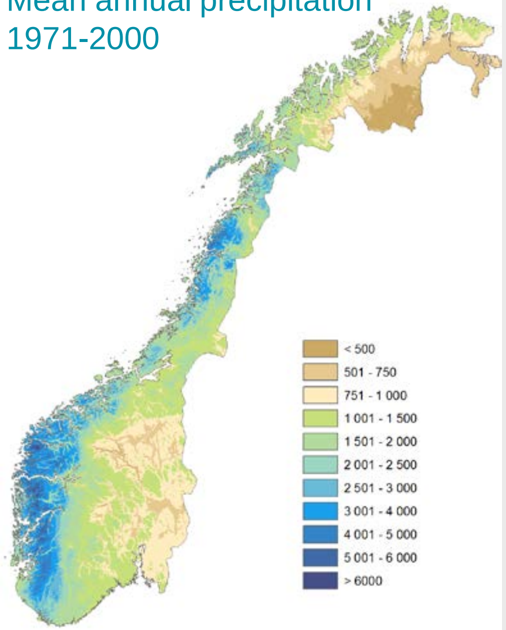
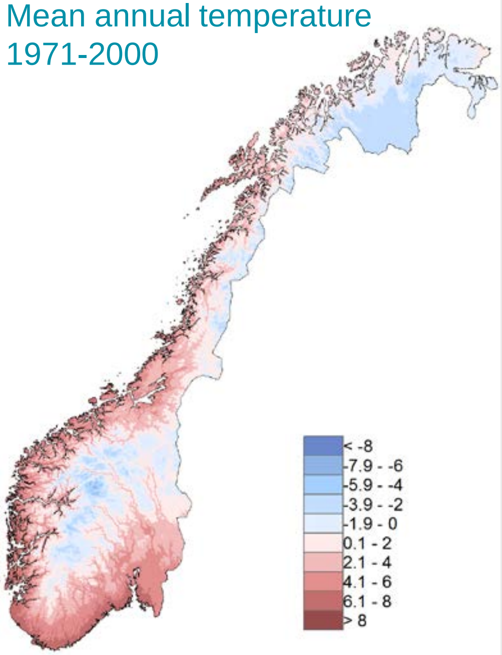
Gridded climate indicators

Mean annual precipitation
1971-2000



Mean annual temperature
1971-2000



Gridded climate indicators

- Climate indicators are condensed climate information to meet specific user demands.

- Degree days and degree day sums
  - Growing
  - Heating

  Nr of days or aggregated sums above/under given thresholds.

- Seasons

- Presented as maps, or as point or area averaged time series.

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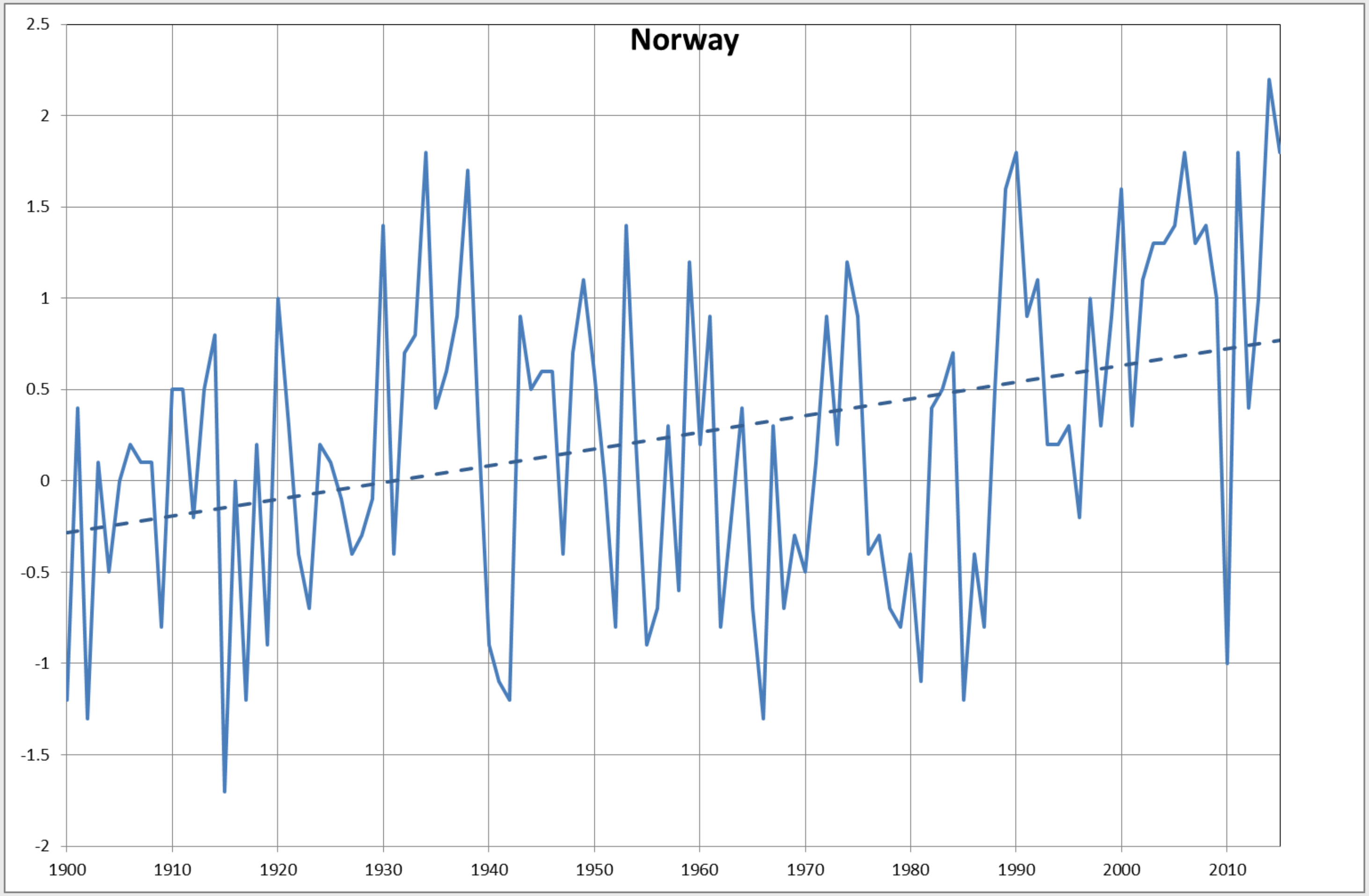
Norwegian annual temperatures



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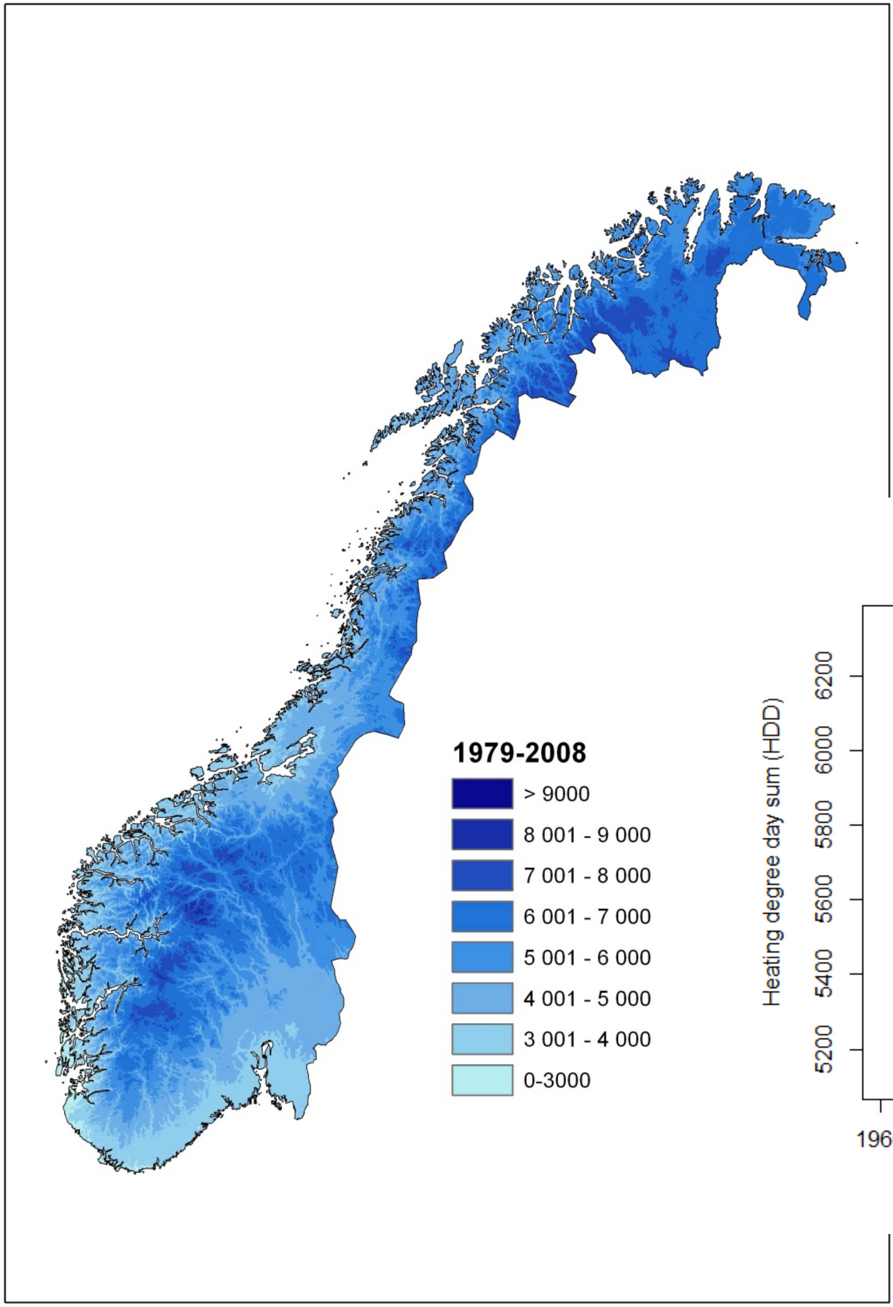
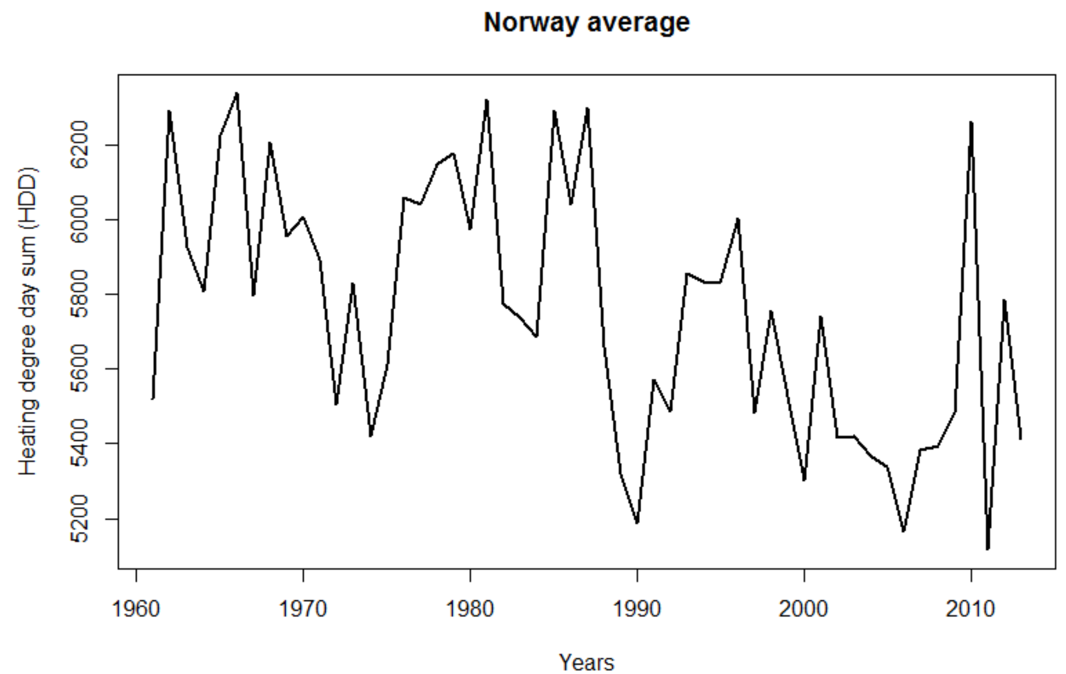
Heating degree days

$$HDD = \sum (17 - TAM) \mid TAM < 10°C$$





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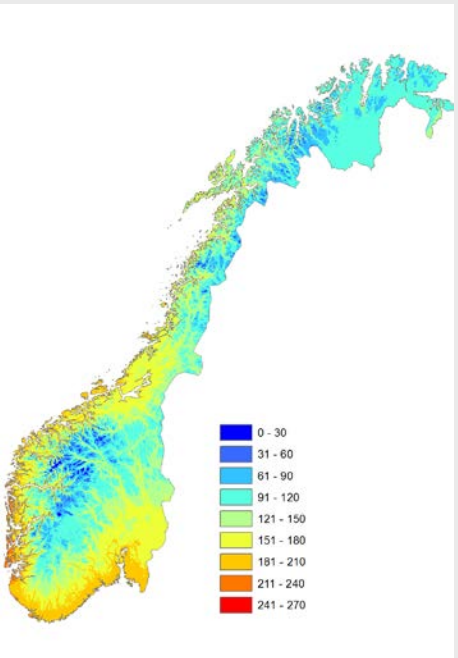
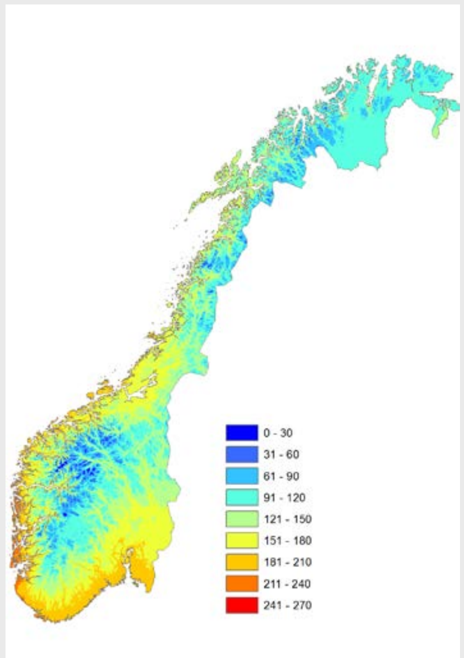
Growing season, length

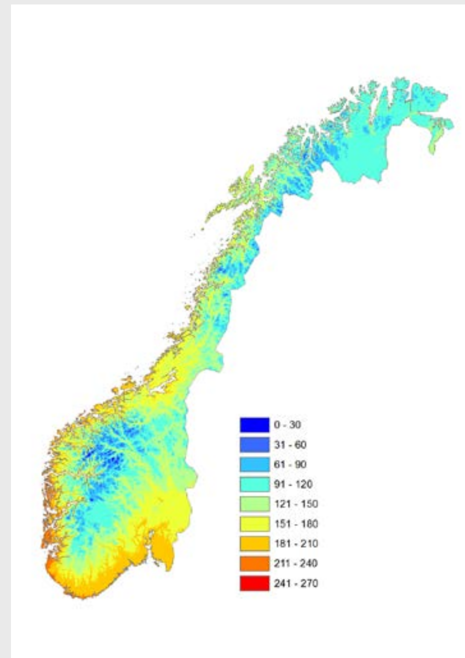
1961-1990



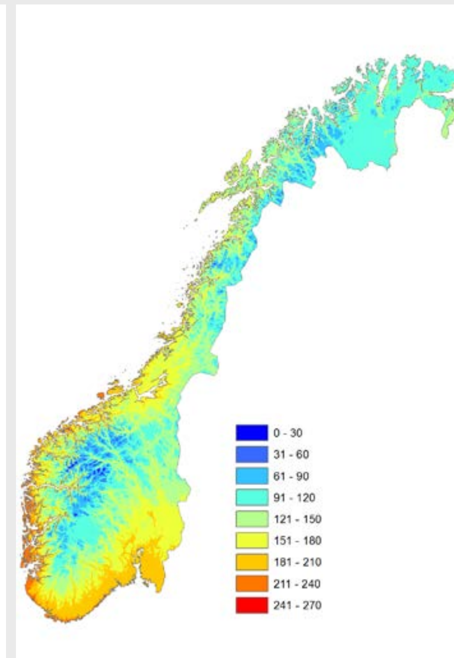
1971-2000



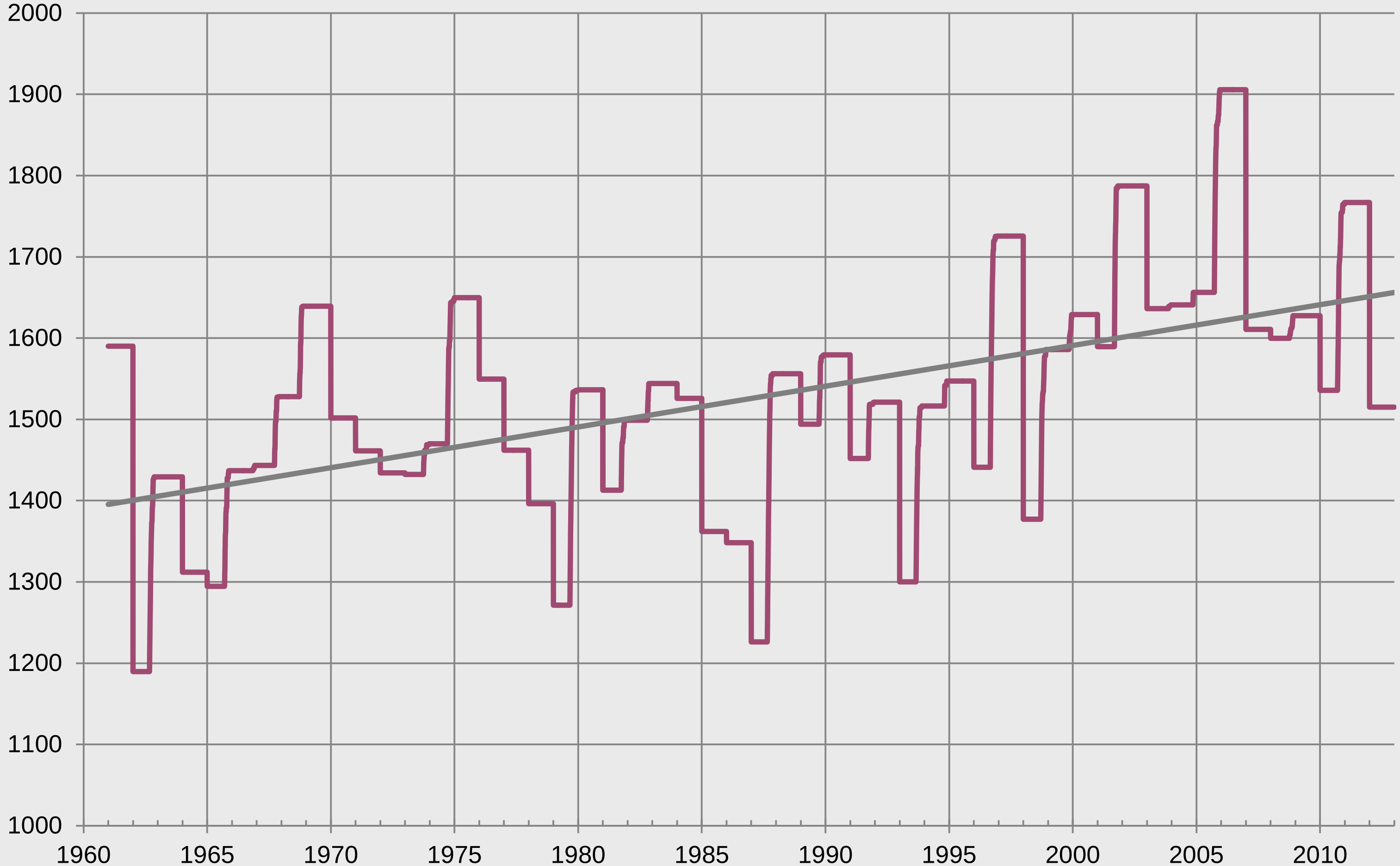
1981-2010



1985-2014

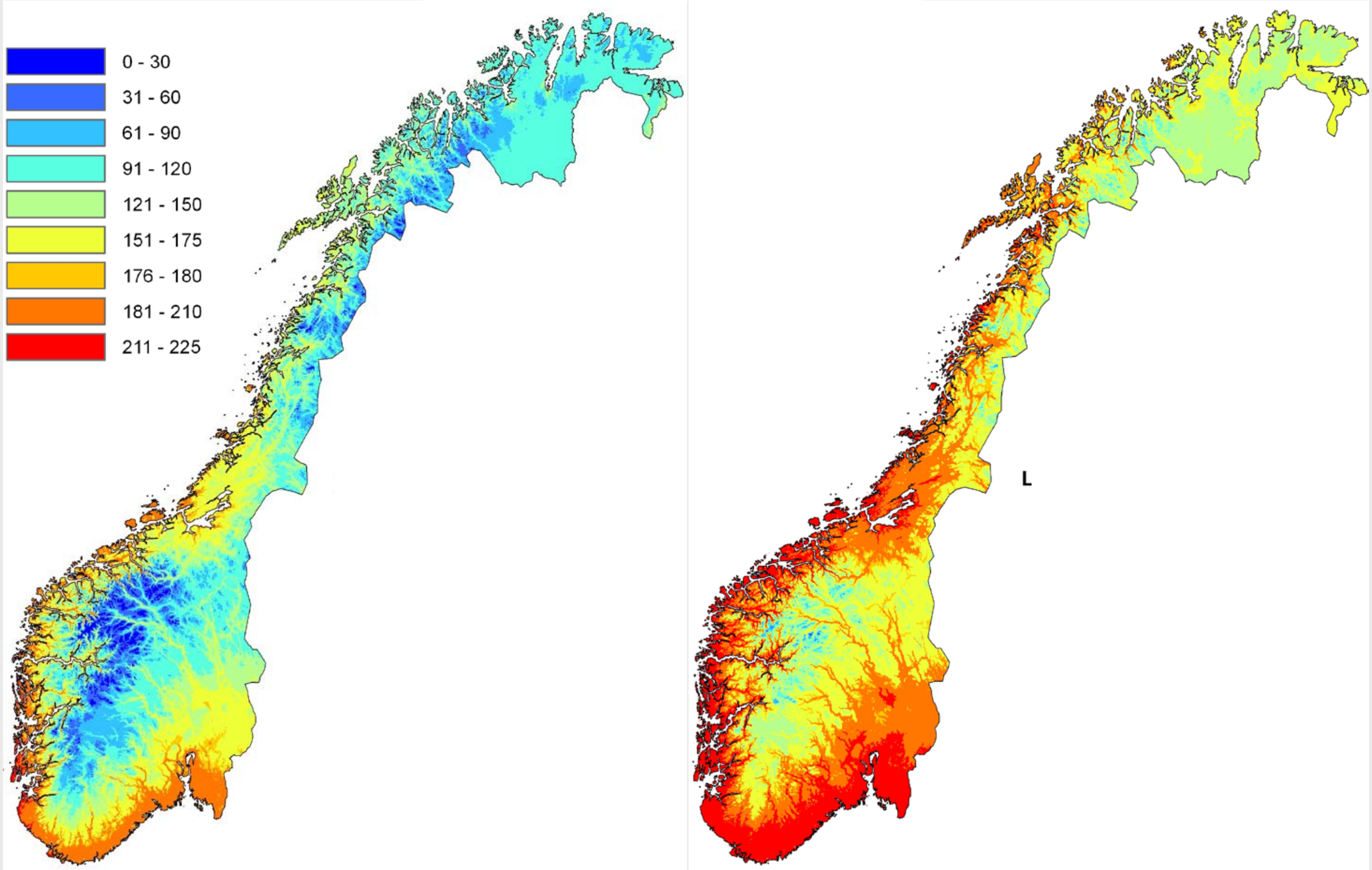


Growing degreedays in Oslo-Blindern 1961-2012



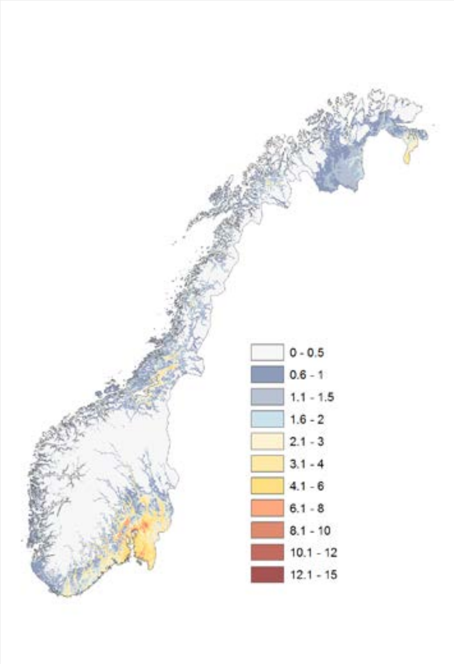
Change of the growing season, HadA2

1961-1990 $GDD = \sum(TAM - 5) \mid TAM > 5°C$ 2071-2100

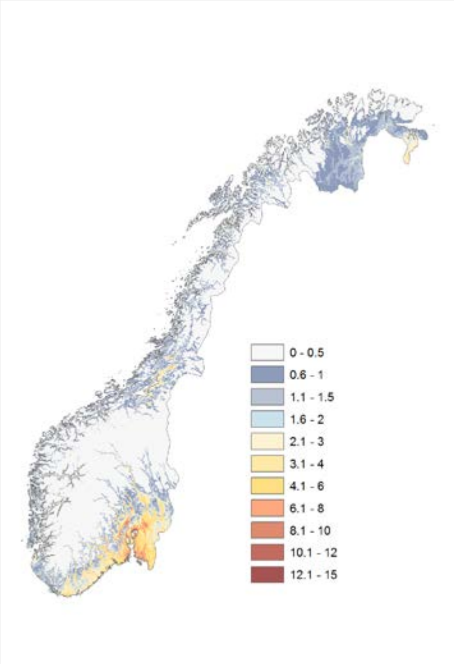


Days > 20 °C

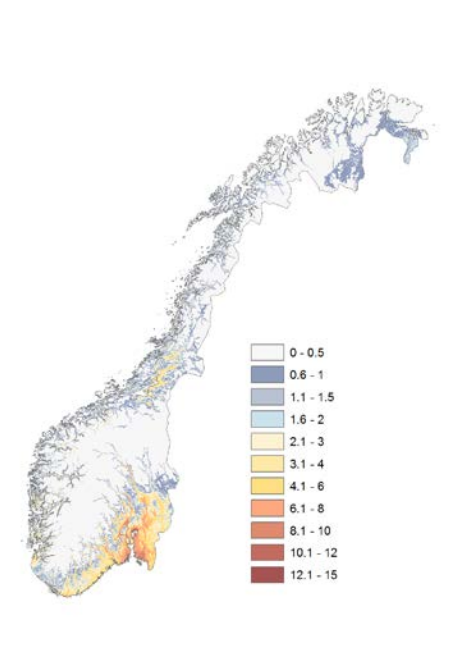
1961-1990



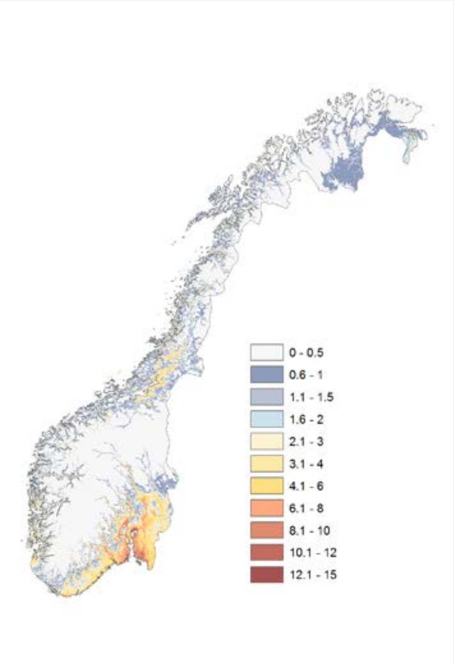
1971-2000



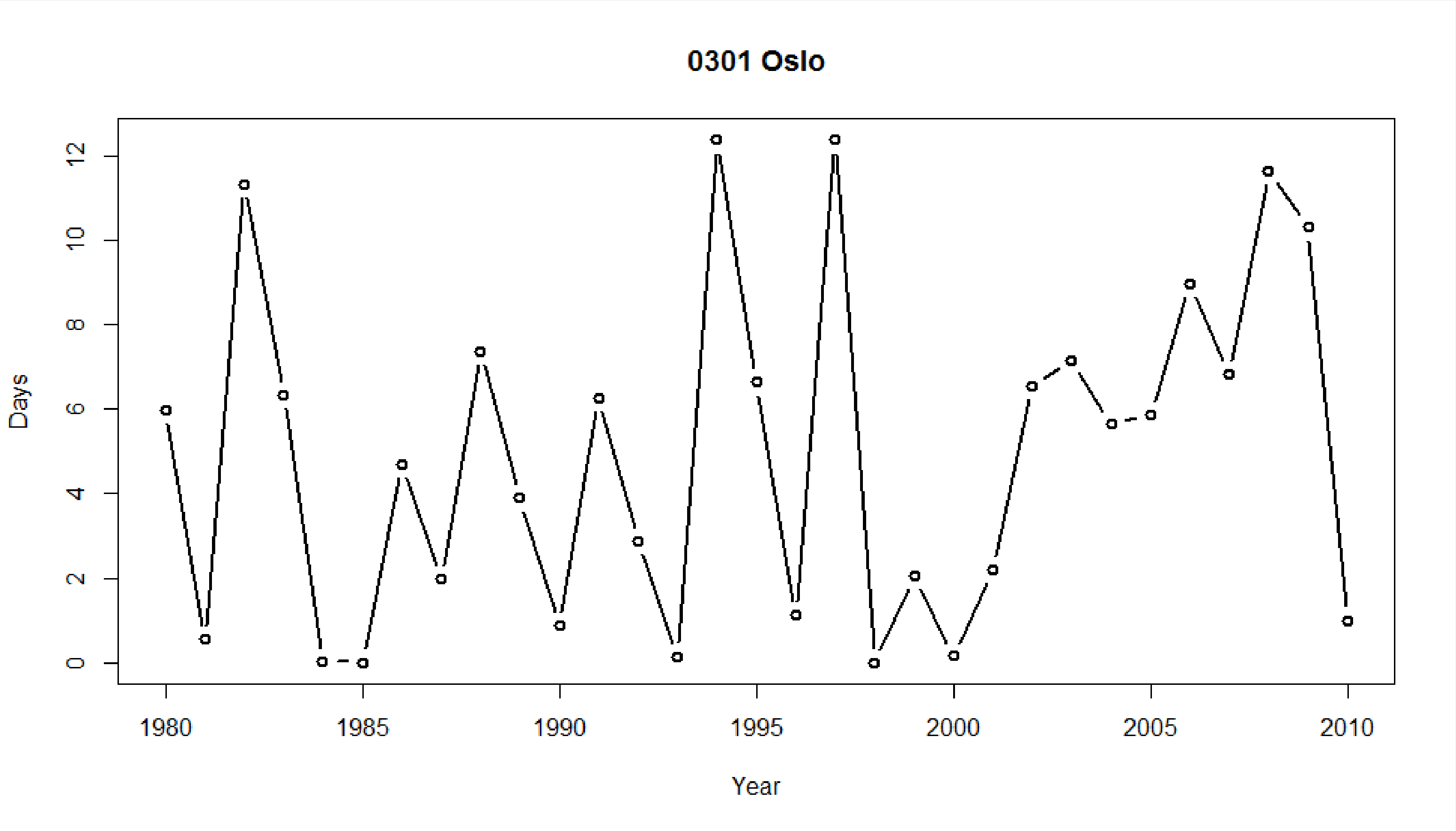
1981-2010



1985-2014



Days > 20°C



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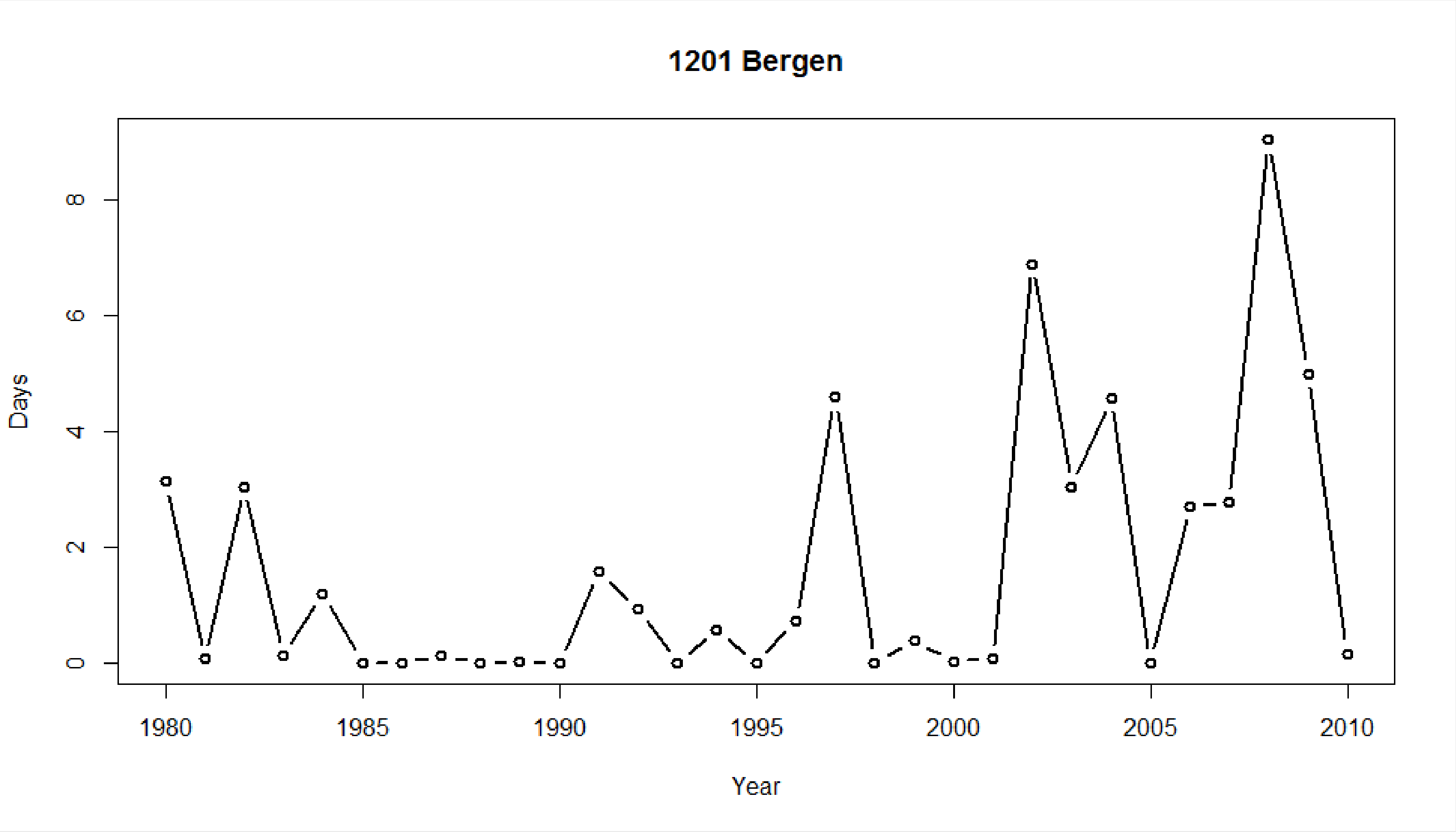
Days > 20°C



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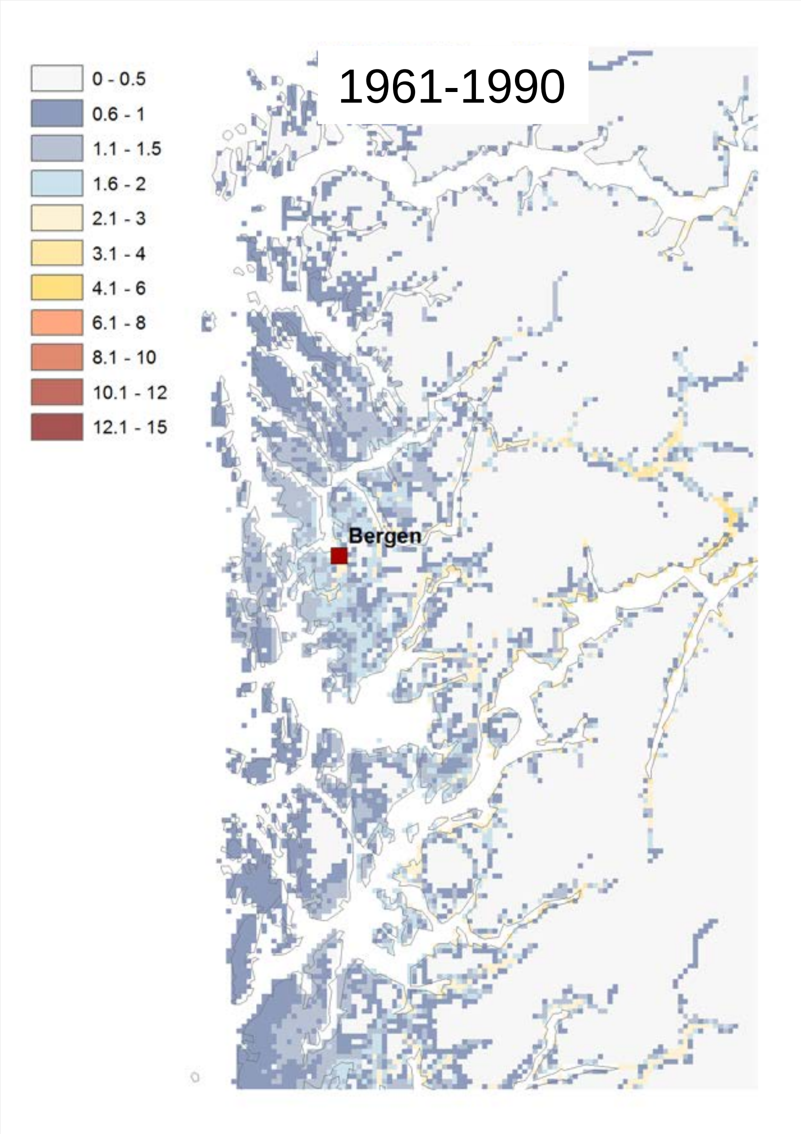
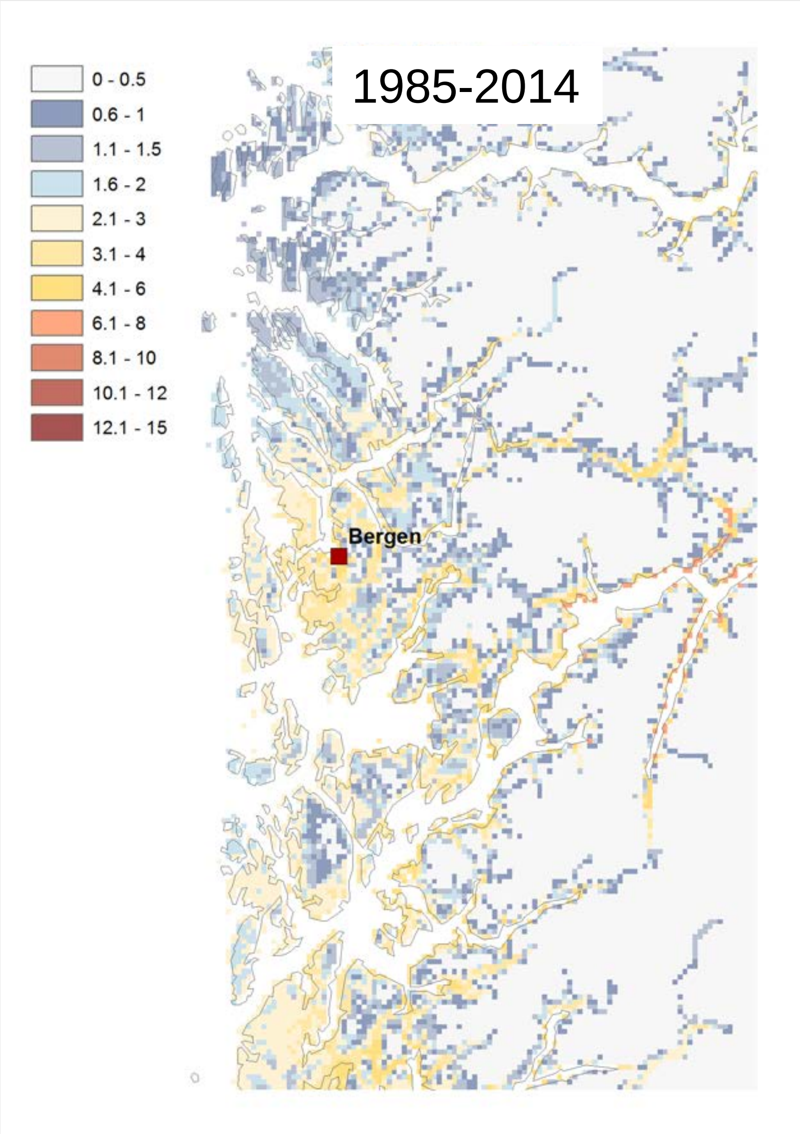
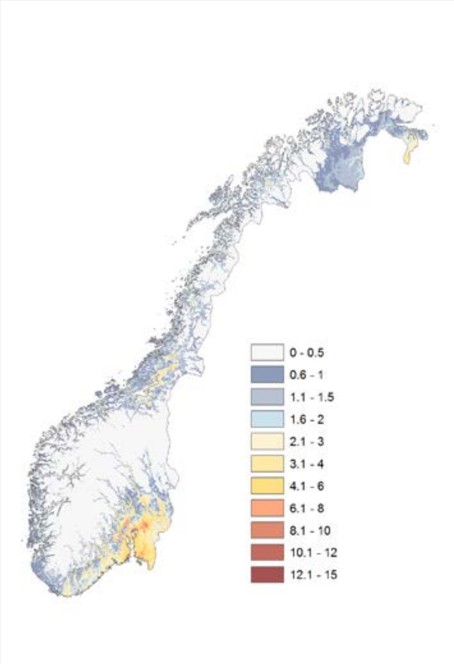
Days > 20°C, Western Norway



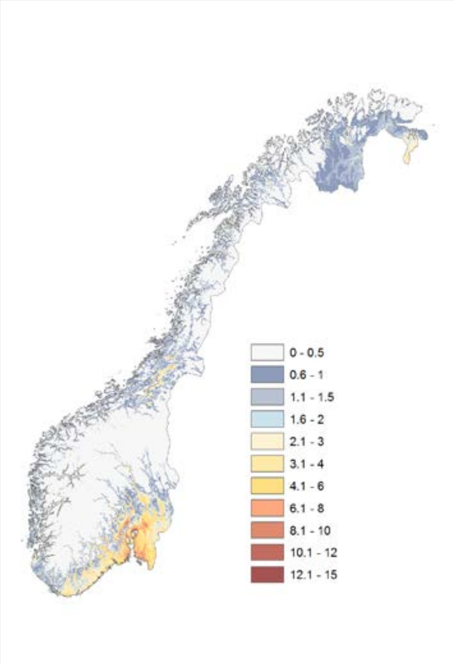


Days > 20 °C

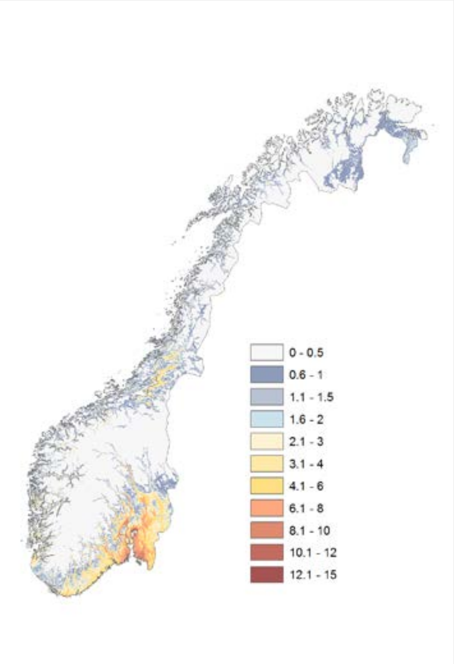
1961-1990



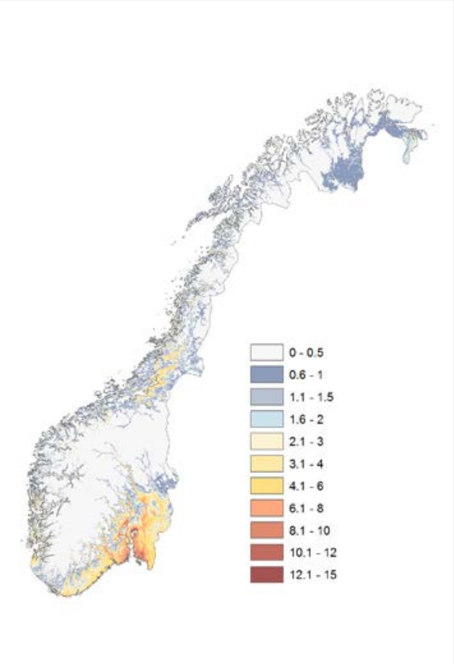
1971-2000



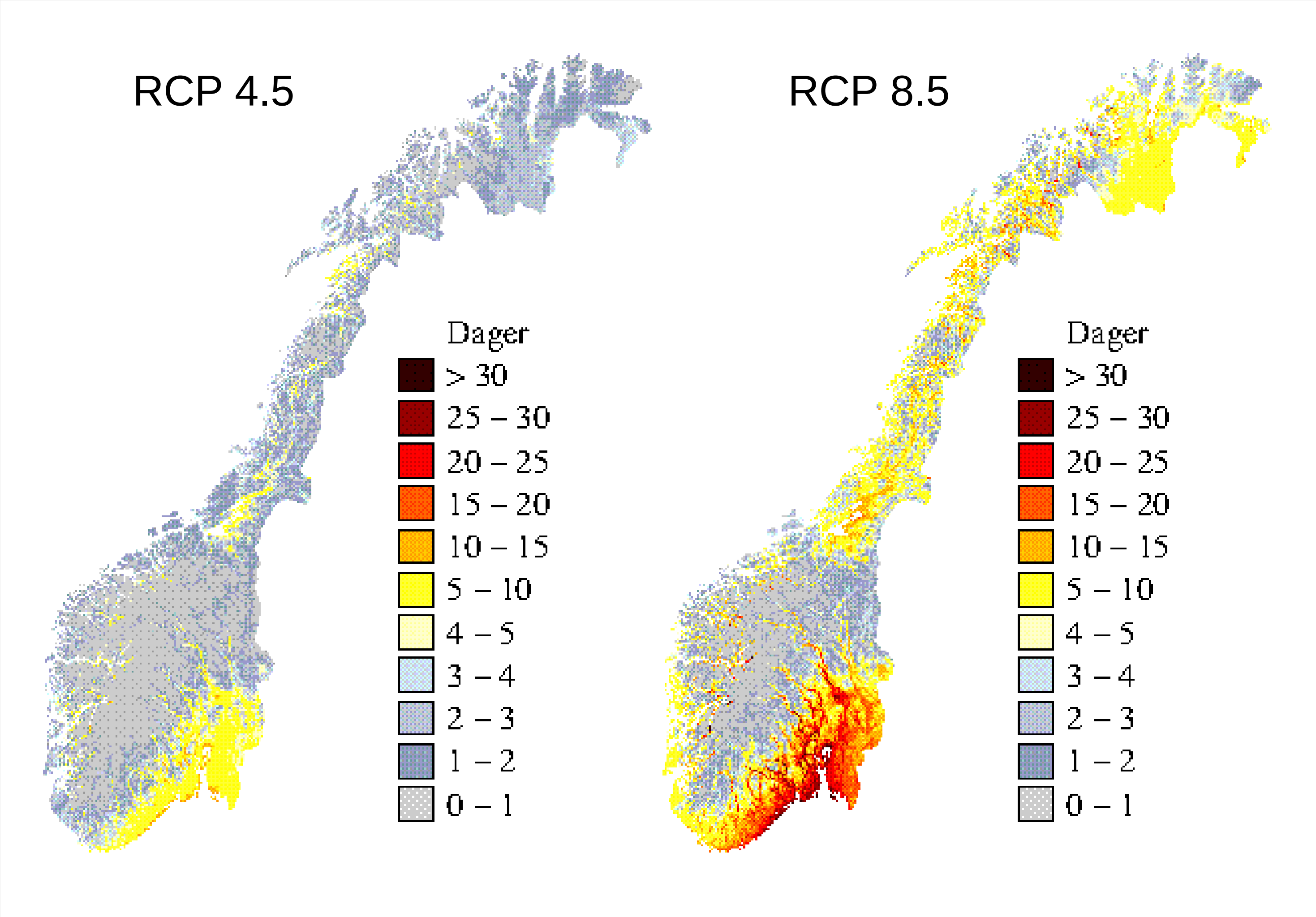
1981-2010



1985-2014



2071-2100



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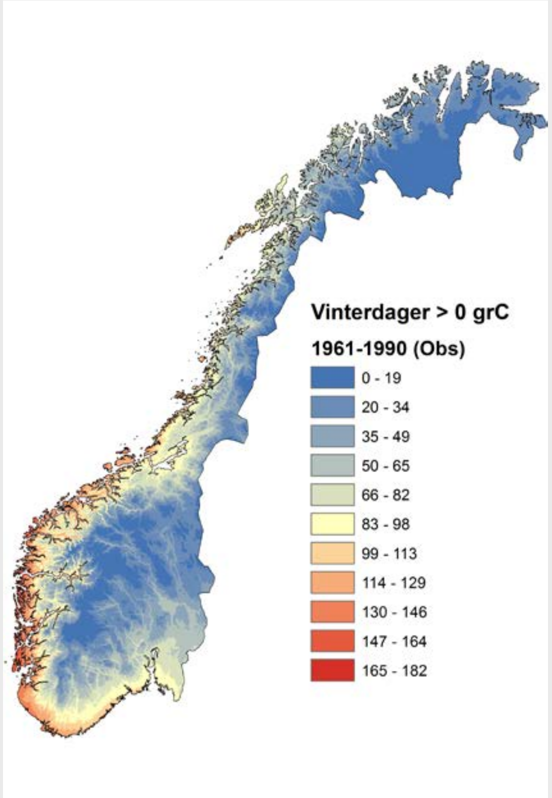
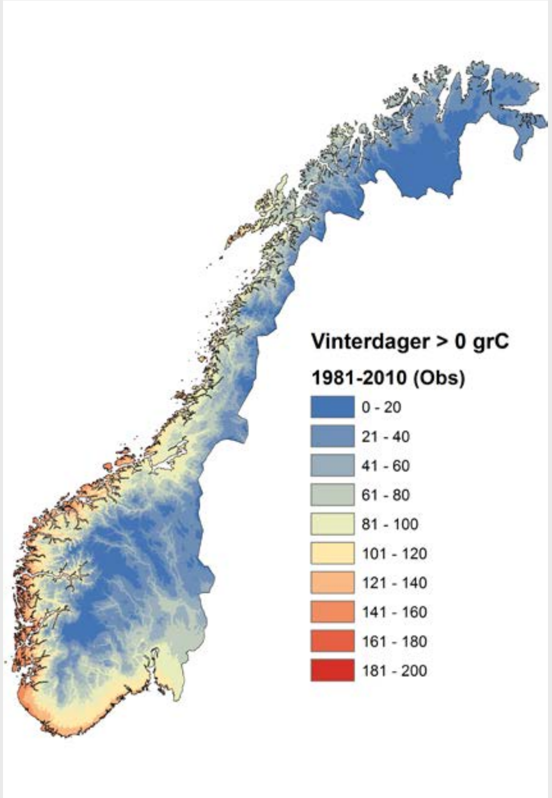
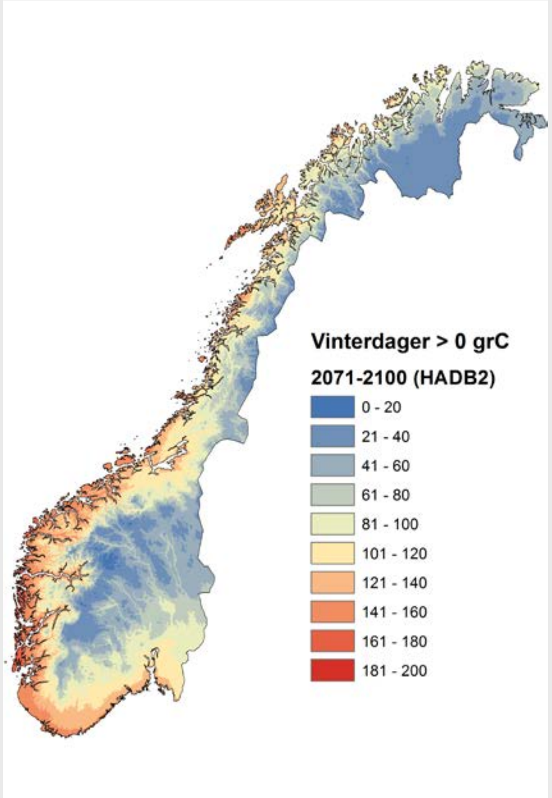
Shorter winters!

- Norwegian less dominant in cross-country skiing?
    - We will still have areas with winter conditions though…..







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Gridding challenges/conclusions

High resolution timeseries are more «noisy» than long-term data series ➔ spatial covariance is lower (estimates are more uncertain) and the «signal» is weaker.

Physical consistency between elements (precip, temperature) will not be retained. That’s also an issue with atmospheric models that include parametrizations

For long-term data with «low» (daily, monthly….) resolution observation gridding provide useful and precise information. For historical dataseries (> 50 years) it is probably the best (only) reference.

Future?

- NWP, RCM and RRA models are «chasing» the spatial resolution of observation gridding.
    - Provide more physical consistent data
    - Wind, humidity, … in complex terrain
    - Spatial scale is an issue. 4-5 x the resolution.
- The gap between observation gridding and atmospheric model approaches for providing climatological data are ready be closed.
    - Apply gridding concepts in post processing of NWP/RA
    - Apply NWP/RA fields as first guess
    - Gridded observations needed for independent validation and bias adjustments of physical atmospheric models
- Apply radar and satellite data.
- (How to) Apply soft information (and "citizen" data)?
    - Lower quality, higher density,
    - complementary data, in addition (and not instead of) regular observations.
    - How to utilize "less reliable" (fuzzy) information

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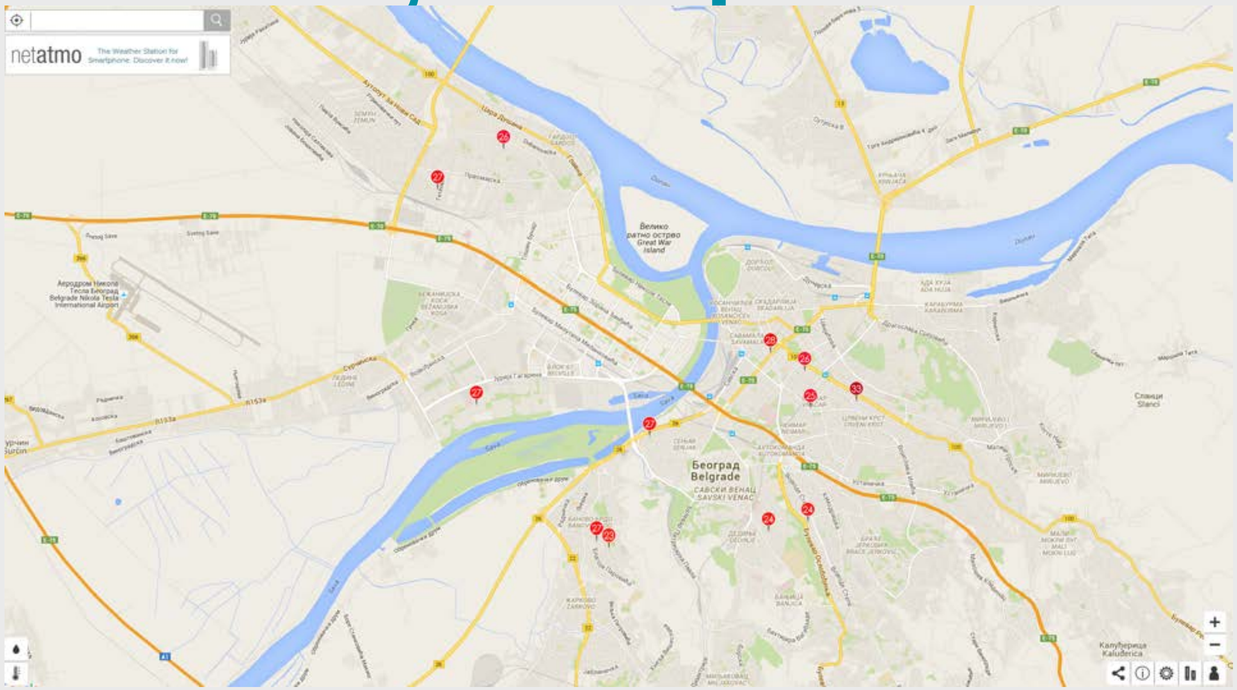
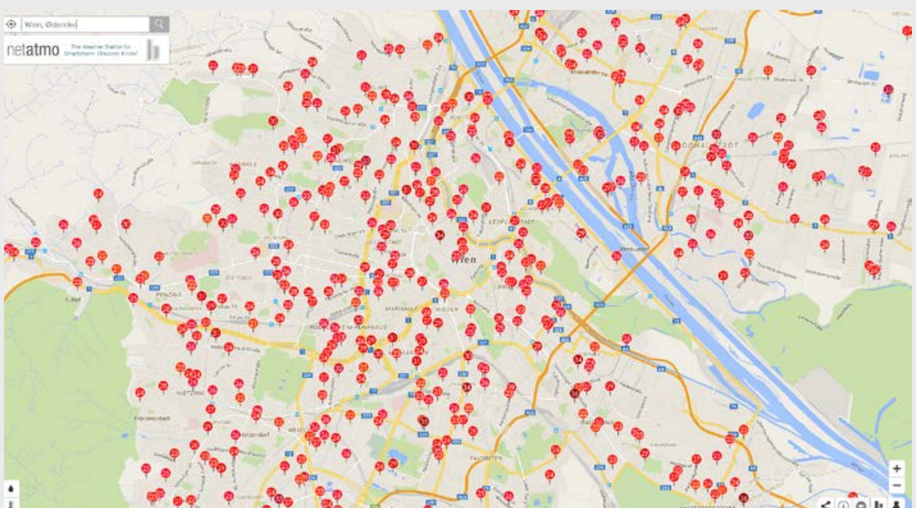
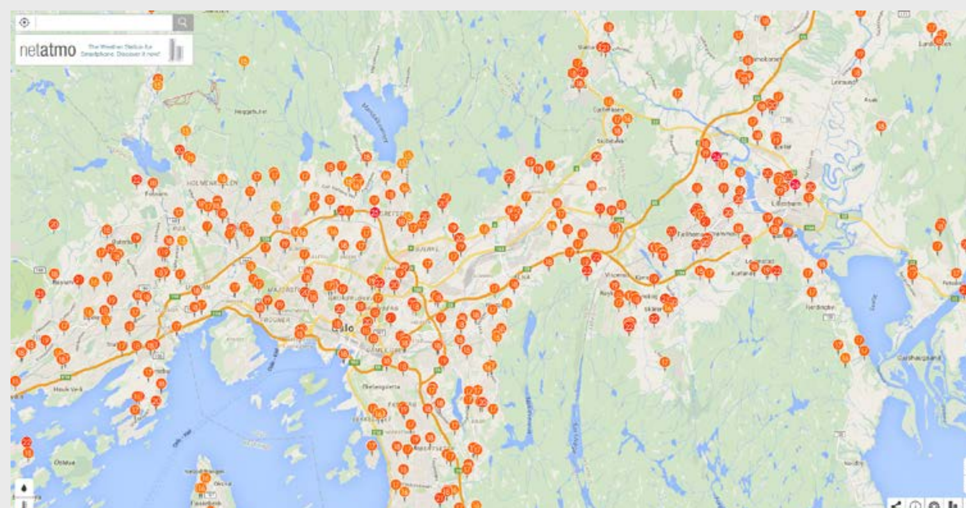
Citizen data, example NetAtmo







Access to data & algorithms

Openess!!!

- Open source software and algorithms
  - R
  - GitHub
- Open access data
  - MET Norway have a open data policy since 2007.
  - Europe is opening up…
- Stimulate partnerships & cooperations

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Thank you
ole.einar.tveito@met.no

Meteorologisk
institutt

150 år