Norwegian Meteorological Institute

Supporting climate services, operational and research challenges

Ole Einar Tveito

with contributions from

Eirik Førland, Inger Hanssen-Bauer, Lars Grinde, Anita Verpe Dyrrdal, Cristian Lussana, Elin Lundstad, Herdis M. Gjelten, Hanna Szewzcyk-Bartnicka

01.05.2016

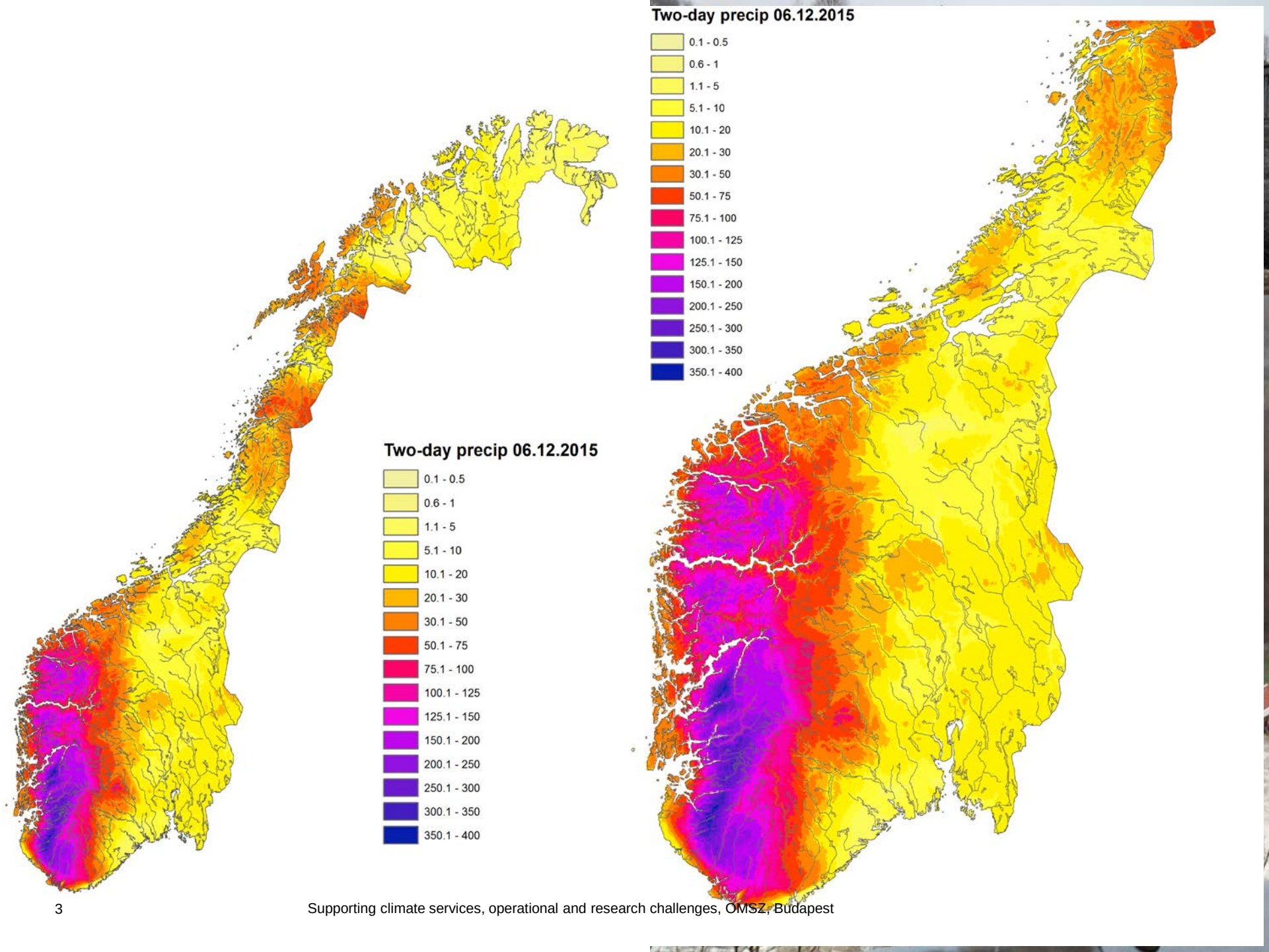
Foto: MORTEN AAKRE, FOTOGRAFEN AS EGERSUND

Photo:Tor Magne Gausdal

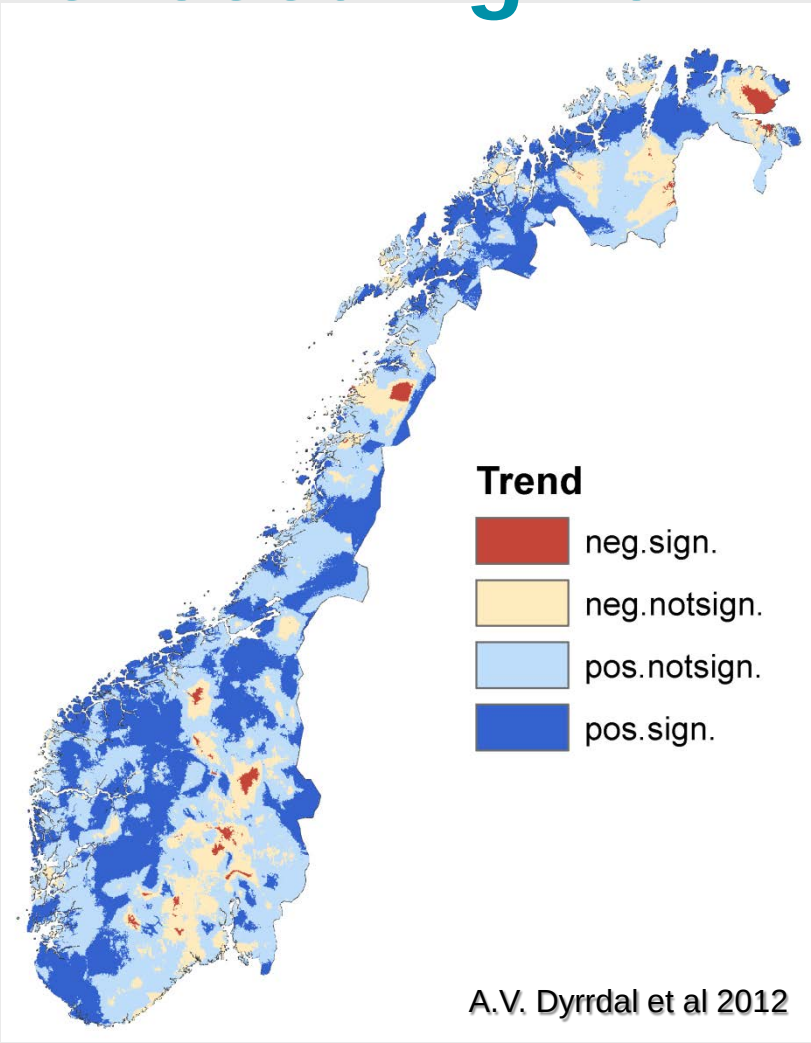
Foto: CARINA JOHANSEN, VG

Kilde: NRK

Foto: Svanhil Eilertsen Lervik


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
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

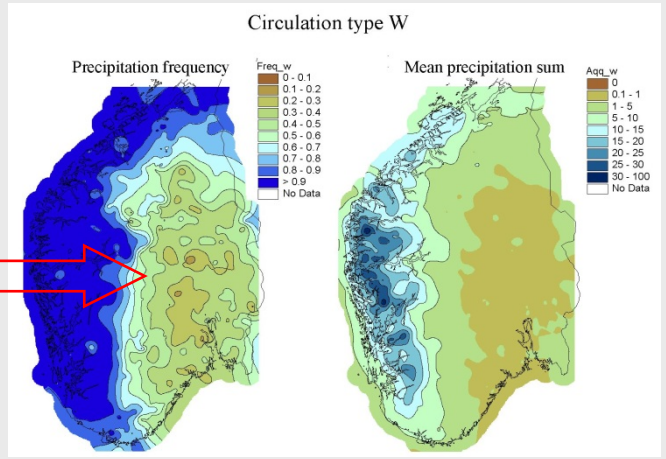
Trends in 1-day precipiation exceeding 10 mm



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

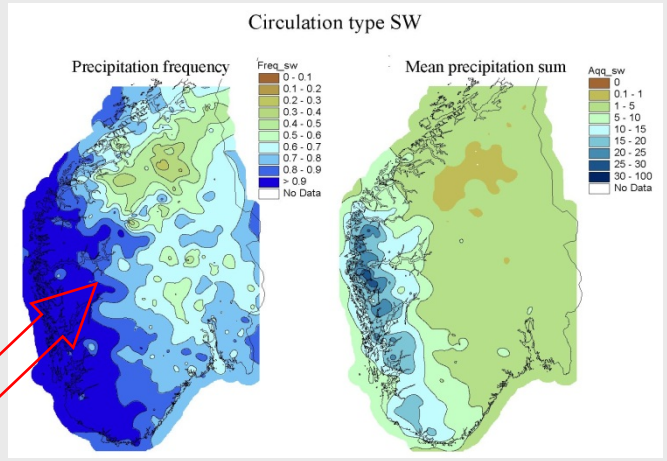
Norwegian Meteorological Institute

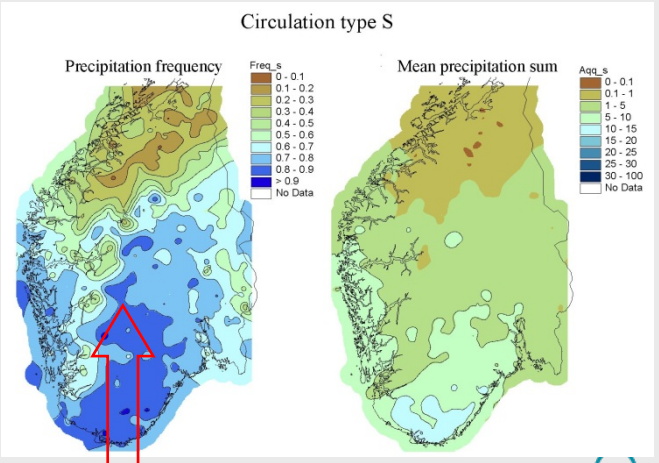
Atmospheric circulation & precipitation



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

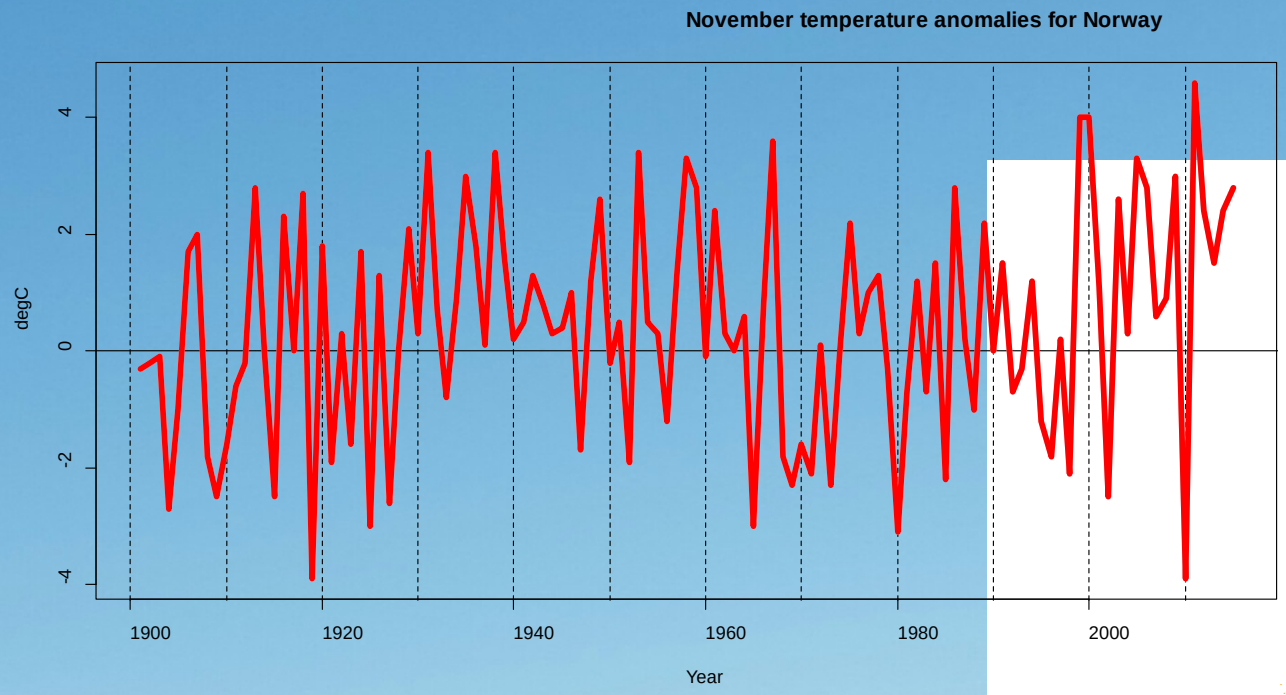
Weather types/circulation indices can therefore be used to give conditional parameterisation of spatial interpolation algorithms of precipitation as well as temperature and other climatic elements.

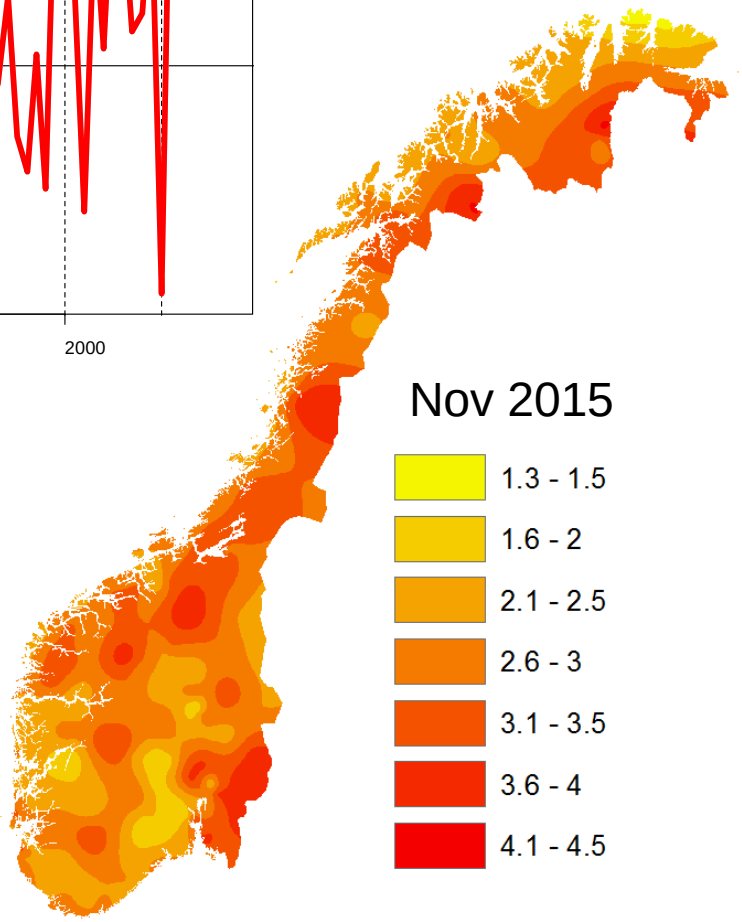




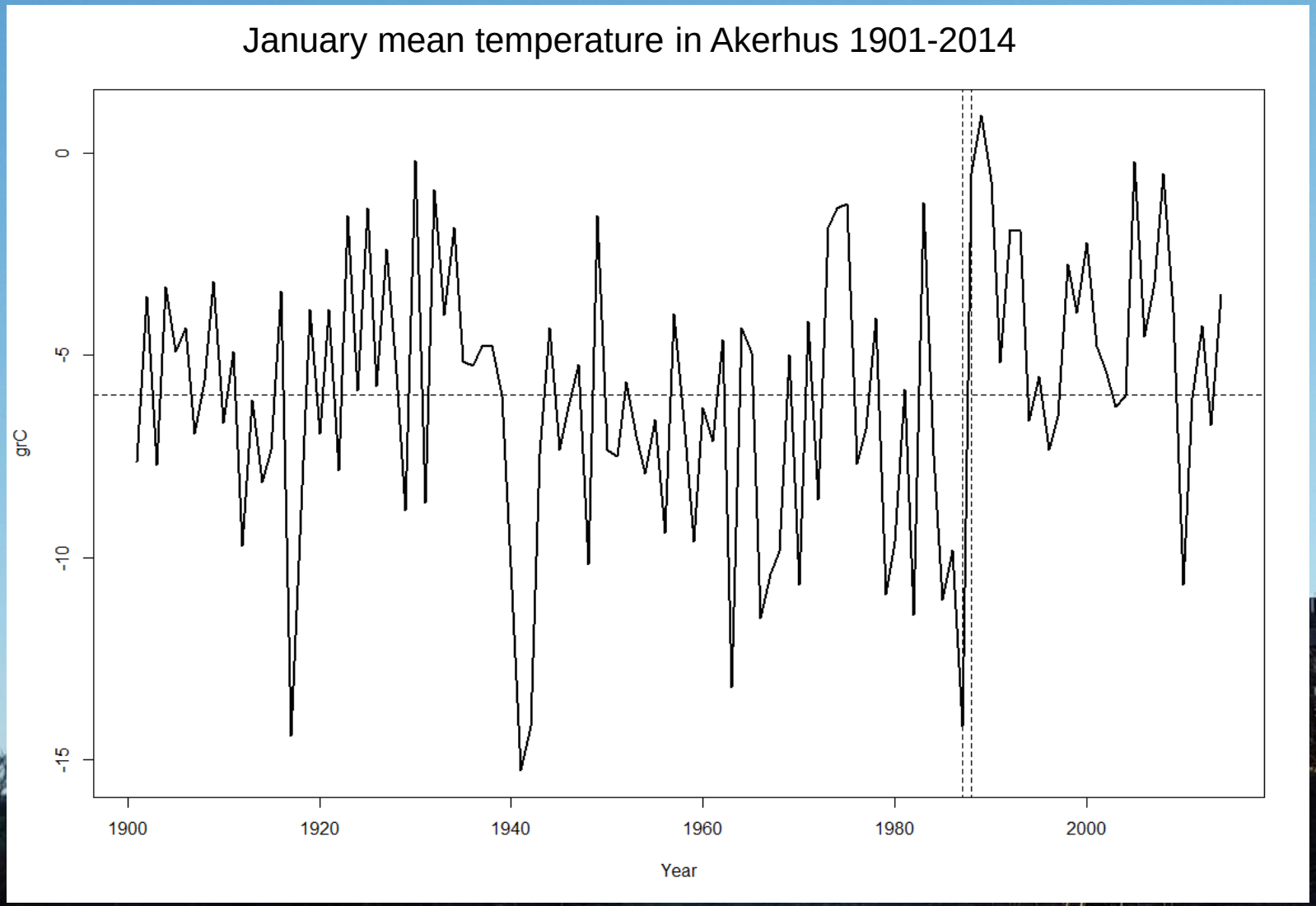
Norwegian Meteorological Institute

Norwegian Meteorological Institute





Norwegian Meteorological Institute



MET Norway

- Founded 1866
- 440 employees in 2015 (→ ~400 in 2017)
- Headquarter in Oslo
- Additional forecast centers in Bergen and Tromsø
- Staff at four airports
- 3 manned observation stations in the Arctic
- 10 (C-band)+1 (X-band) weather radars.

MET Norway - mission

To ensure that governments, businesses, institutions and the public have the opportunity to secure the lives and values with respect to weather and climate.

- To provide best possible basis for planning and environmental protection.

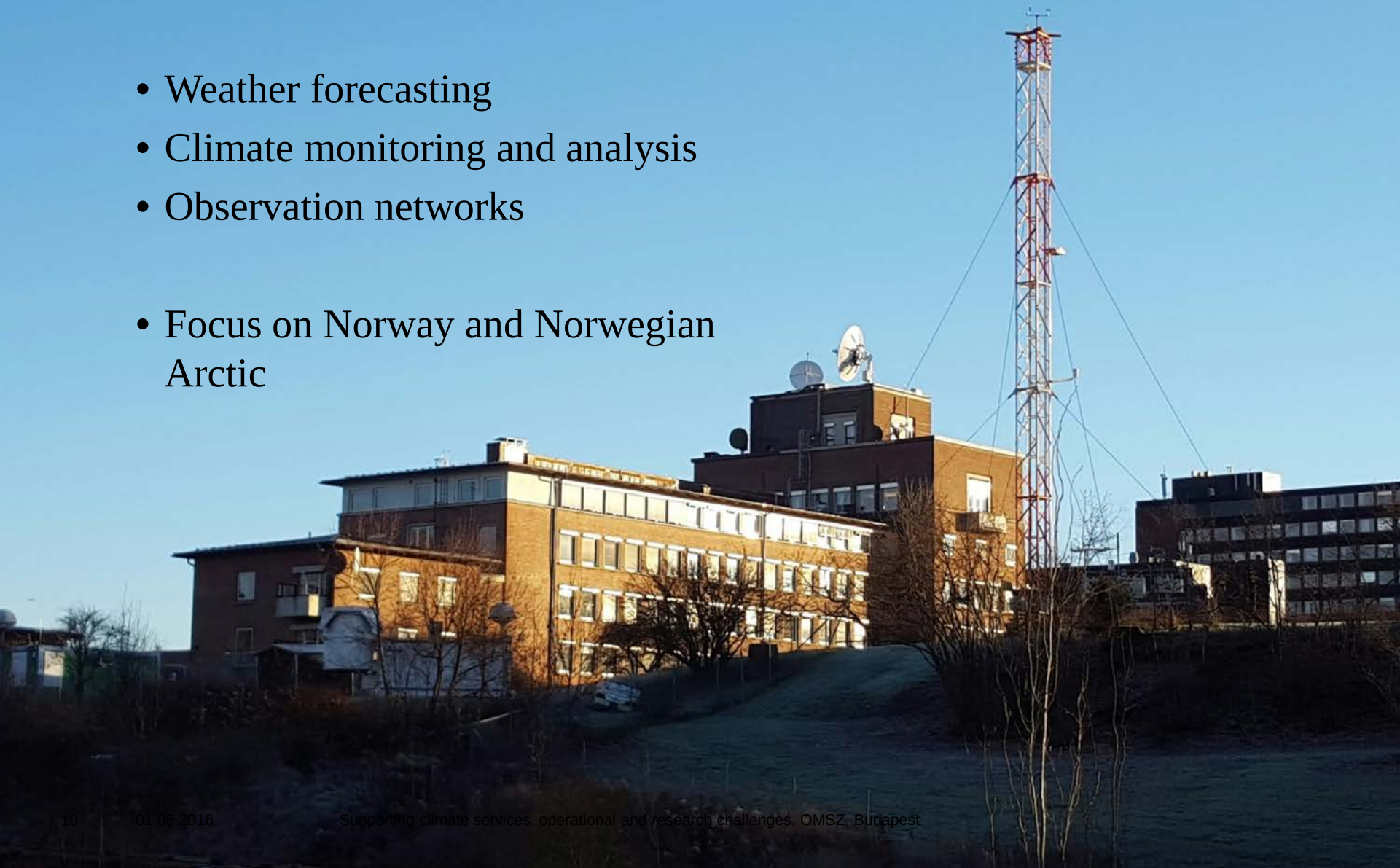
- Forecasting ➔ monitoring and **warning**
- Climate ➔ planning, preparedness, design values, risk assessments…

- Provide information about weather and climate at any location, independent of observation locations, for climate adaptation

MET Norway

- Weather forecasting
- Climate monitoring and analysis
- Observation networks

- Focus on Norway and Norwegian Arctic

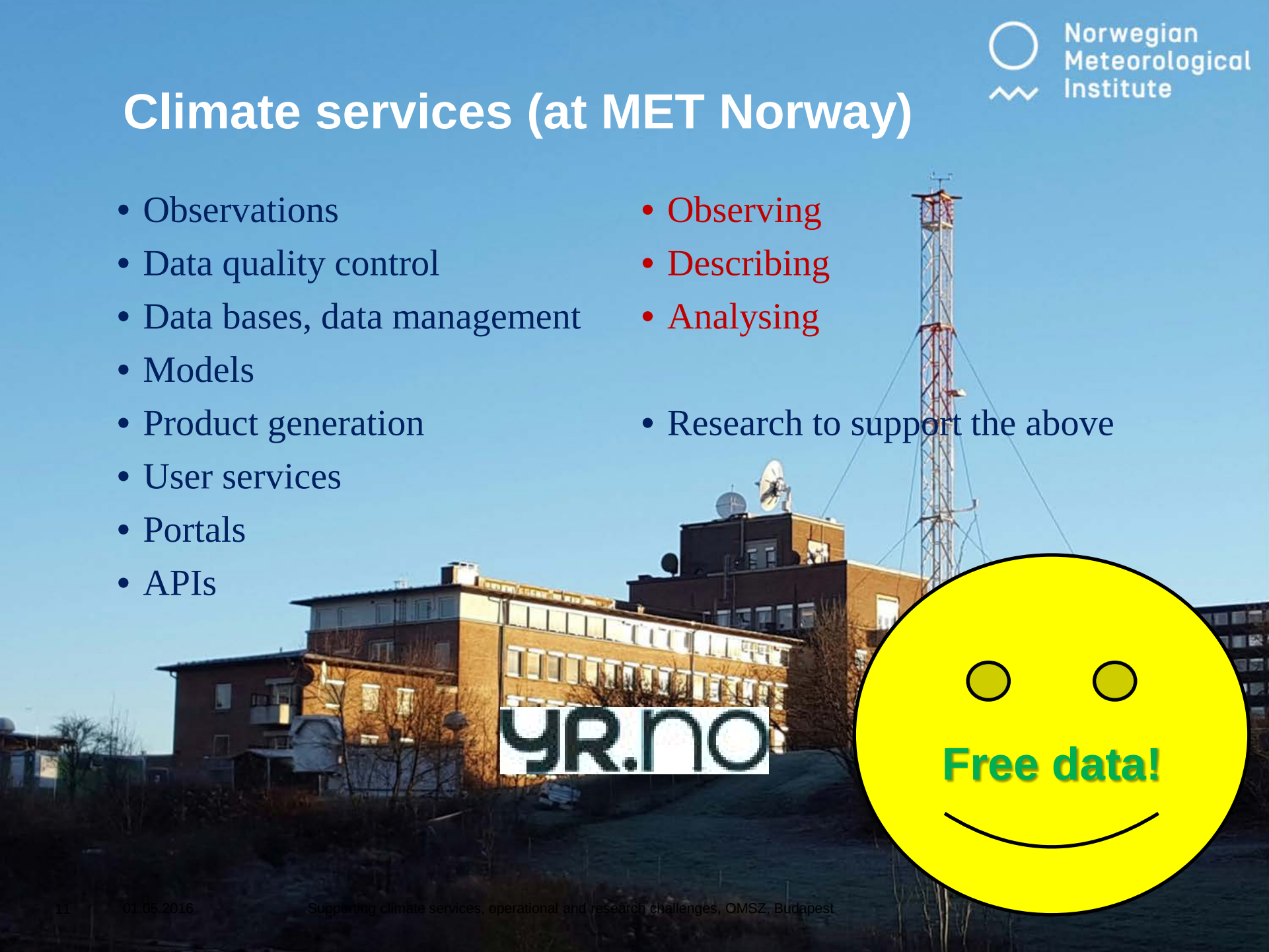


Climate services (at MET Norway)

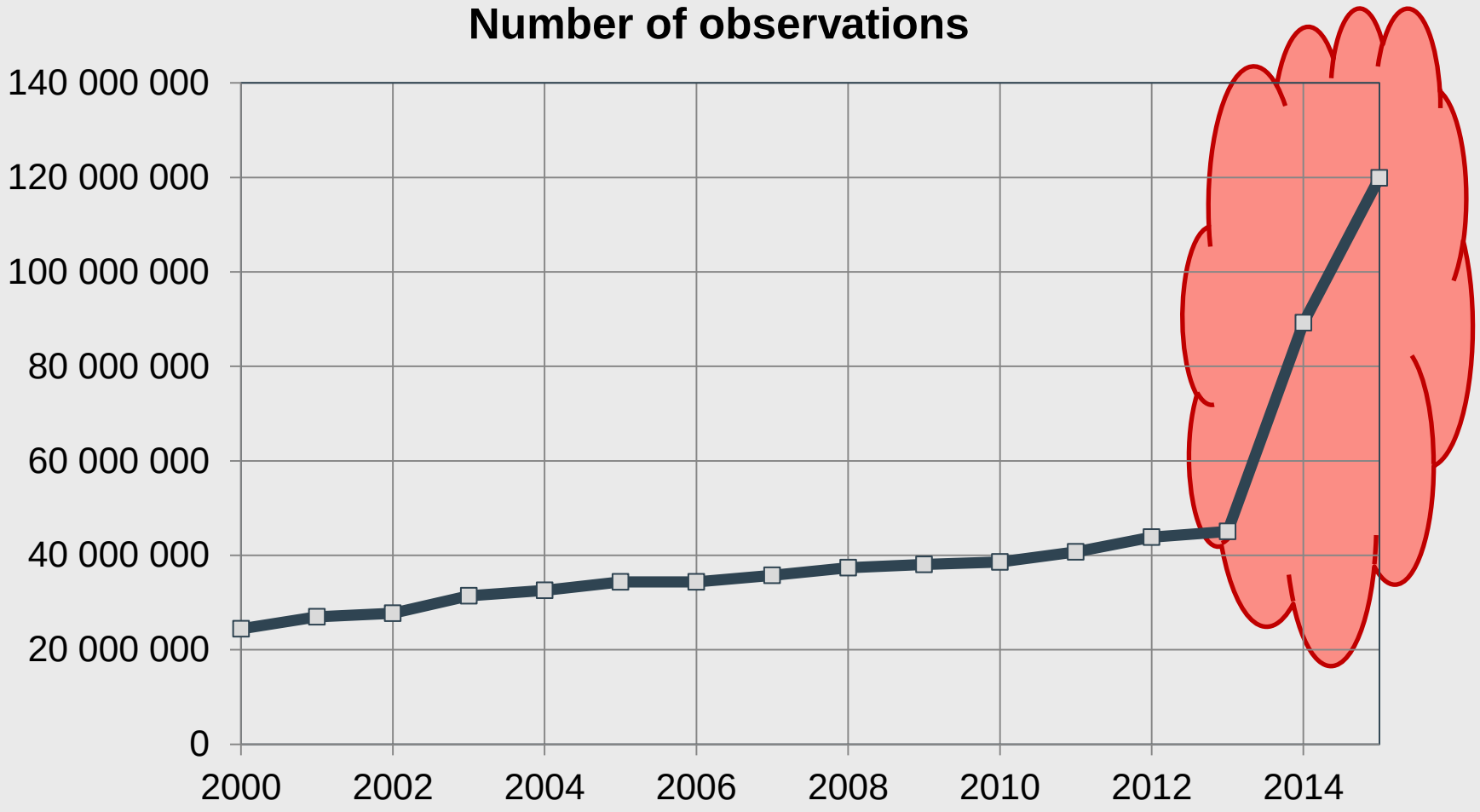
- Observations
- Data quality control
- Data bases, data management
- Models
- Product generation
- User services
- Portals
- APIs

- Observing
- Describing
- Analysing

- Research to support the above

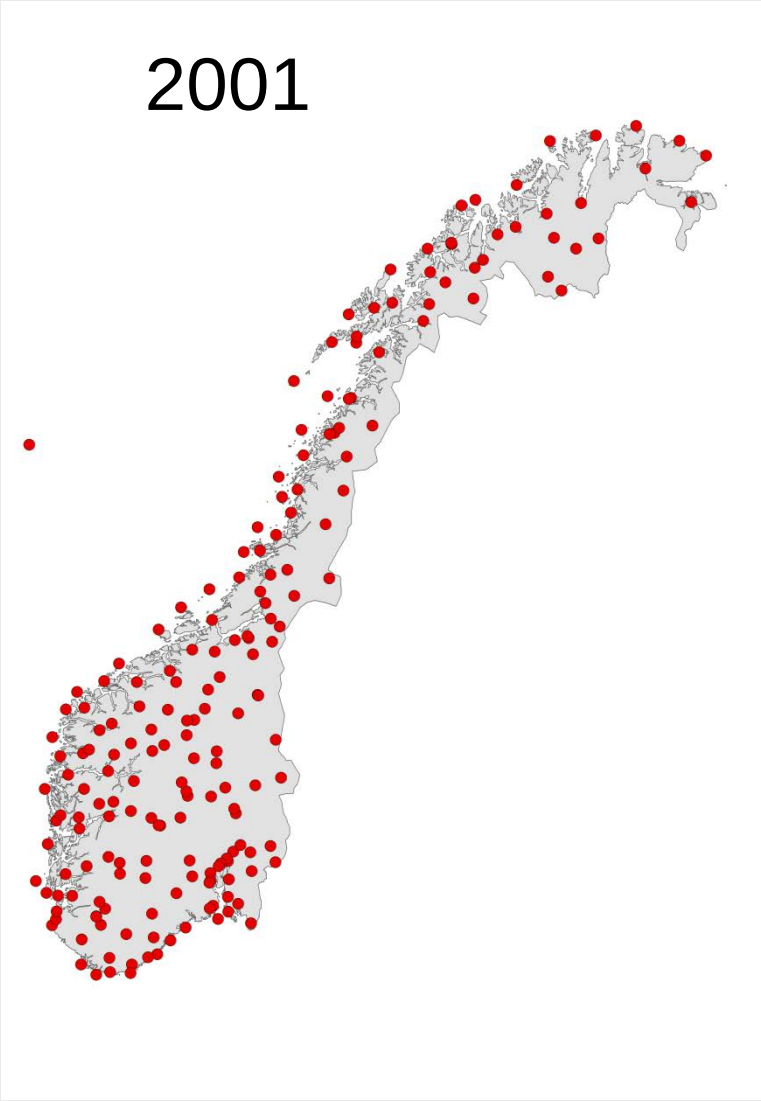


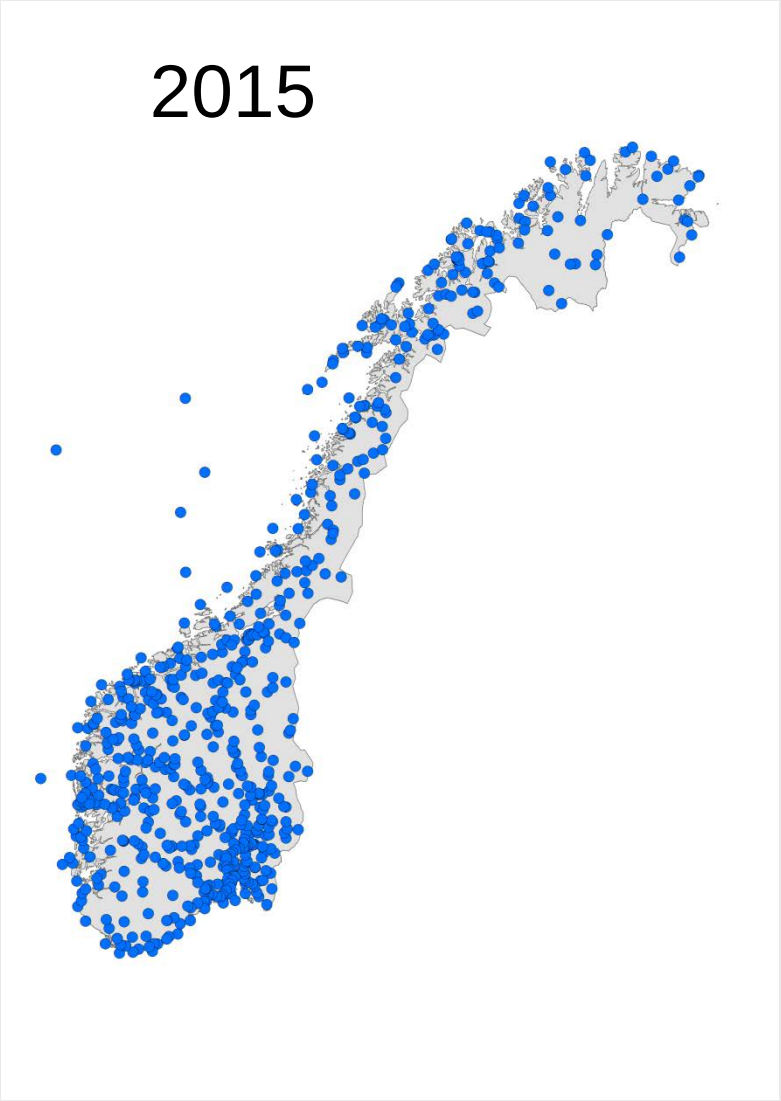
Explosive increase in observations.

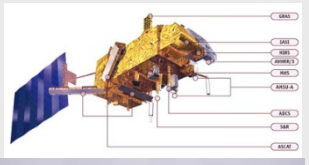


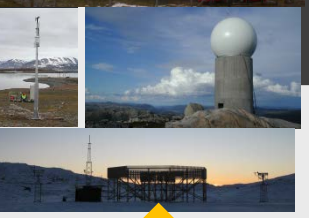
Norwegian Meteorological Institute

Temperature observations (06 UTC)









Analysis

QC

Climate Databases

Product generation

Data ware house

USERS

Data portals

API

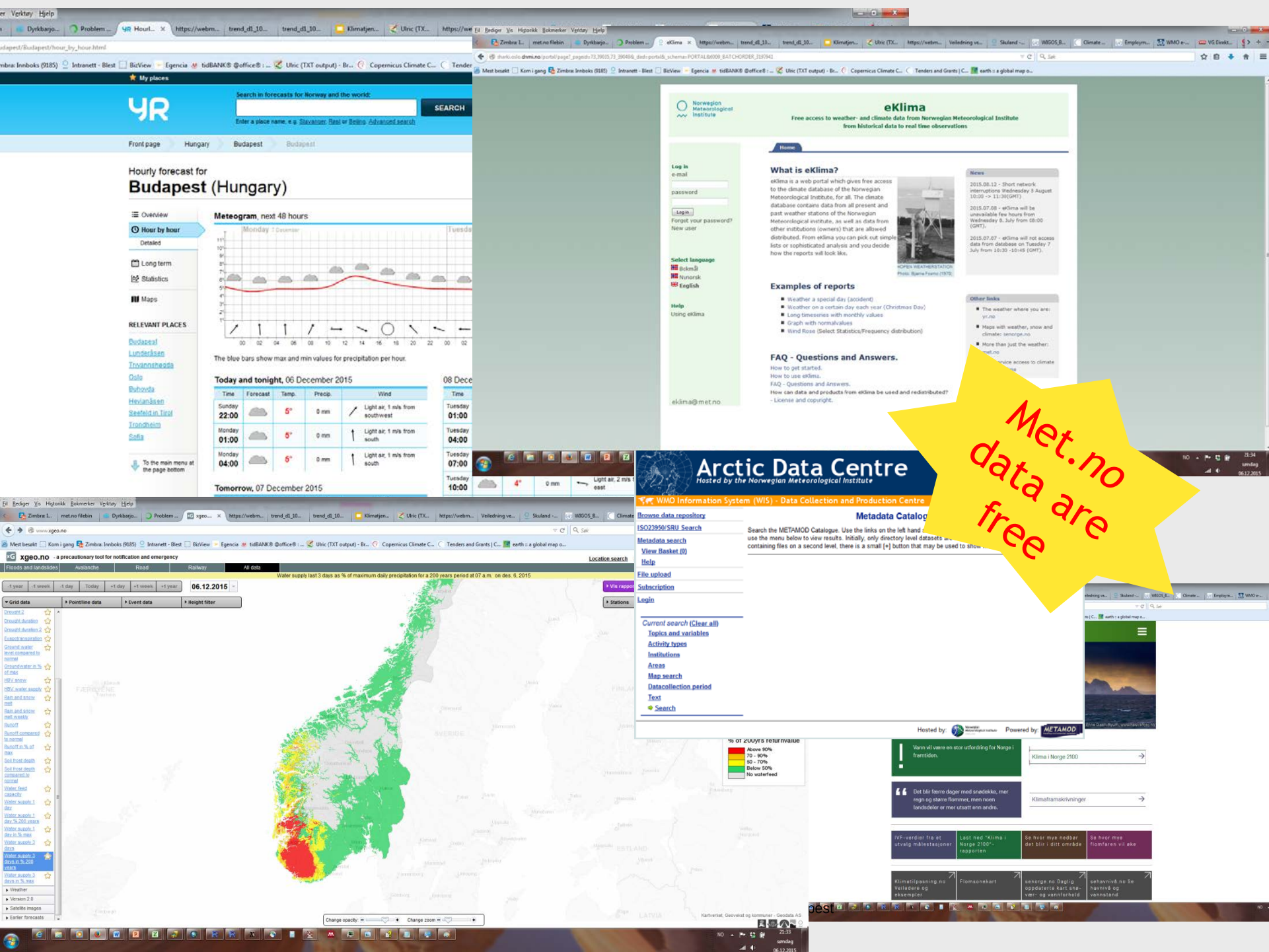
User feedback and partnerships

Operations

Research

Services

Norwegian Meteorological Institute

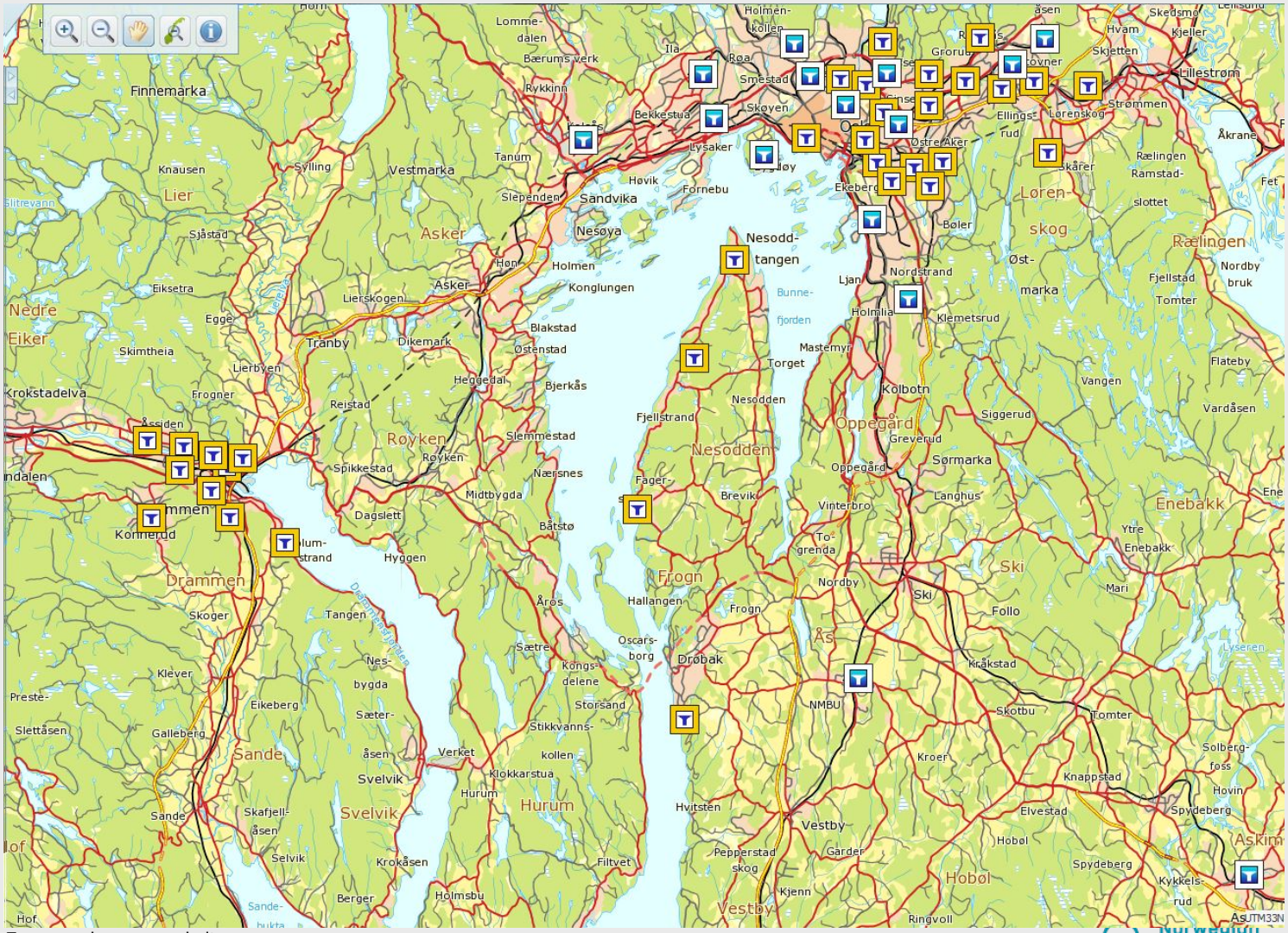

yr
Hourly forecast for
Budapest (Hungary)
Meteogram, next 48 hours
Today and tonight, 06 December 2015
Tomorrow, 07 December 2015
eKlima
Free access to weather- and climate data from Norwegian Meteorological Institute
from historical data to real time observations
What is eKlima?
Examples of reports
FAQ - Questions and Answers.
Arctic Data Centre
Hosted by the Norwegian Meteorological Institute
WMO Information System (WIS) - Data Collection and Production Centre
Metadata Catalog
xgeo.no
Met.no data are free

Focus! Extreme weather…

Estimate design values

- Heavy (intense) precipitation: A new framework for T-year precipitation is developed (PhD-defence last week) and ready to be implemented.
- PMP: Ongoing PhD project ongoing estimation of PMP applying NWP-model(s)
- Modelling precipitation by combining observations, radar and NWP
- Atmospheric icing: Improve micro-physics in NWP-models to estimate ice loads on power transmission lines….
- Wind climate in complex terrain, atmospheric re-analaysis.

Tight clusters of rain gauges



From regnbyge.no website

Norwegian Meteorological Institute

Status

- Data
  - We receive data from 27 tipping bucket rain gauges in Oslo, 9 in Drammen
  - A X-band radar was installed in central Oslo May 11th.
  - Cross- verification of obervations from the X- and C-band radars
  - Combine radar observations and in-situ observations from a high density rain-intensity tipping bucket gauges.

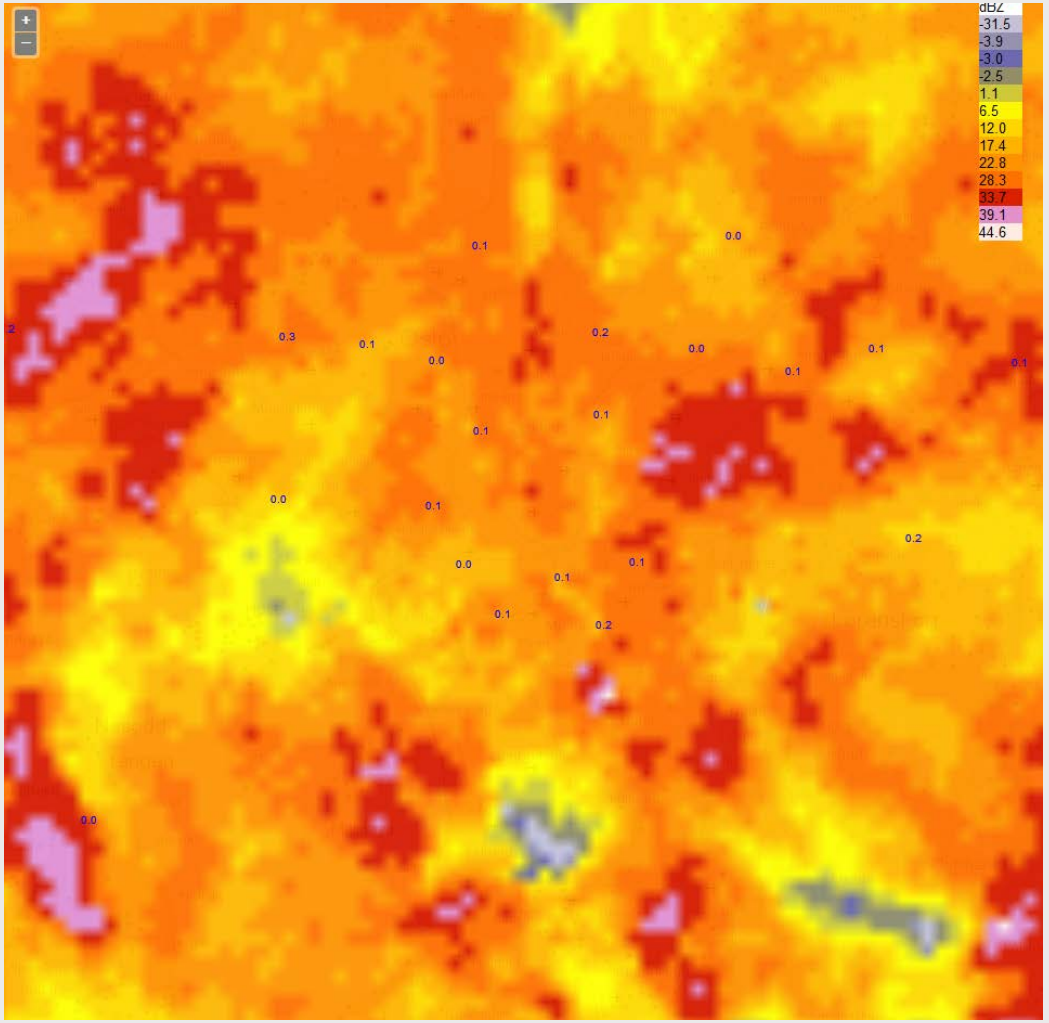
Supporting climate services, operational and research challenges, OMSZ, Budapest

Norwegian Meteorological Institute

Observations

- Rain showers tend to not be registered by the rain gauges
- Are we underestimating how much precipitation hits the catchment?

2. September 2015 ➔ severe flooding in the Lørenskog area (north-eastern parts of Oslo)



Radar group MET

Norwegian Meteorological Institute

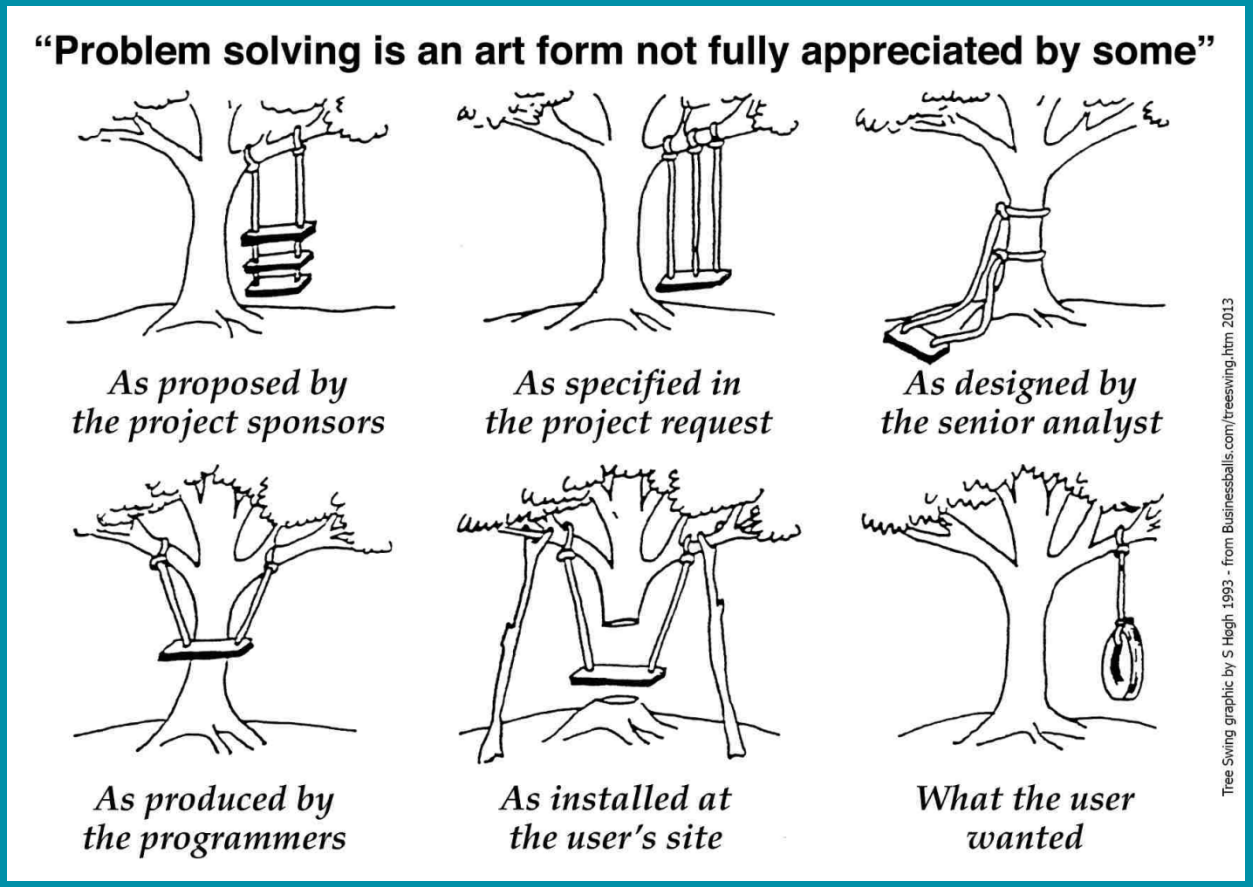
Norwegian Meteorological Institute

User services

What do the users need?

Norwegian Meteorological Institute

Make it as simple as possible and necessary



Climate indicators

Explaining complex and multivariate climate data by **Simplified** and **Condensed** indices in order to stratify information about climate and climate variability.

- Developed to meet specific user needs.
- Based on standard climate elements, alone or in combinations, conditioned or not.

Norwegian Meteorological Institute

Gridded data

-climate indicators as maps

Area averaged maps
Municipality level

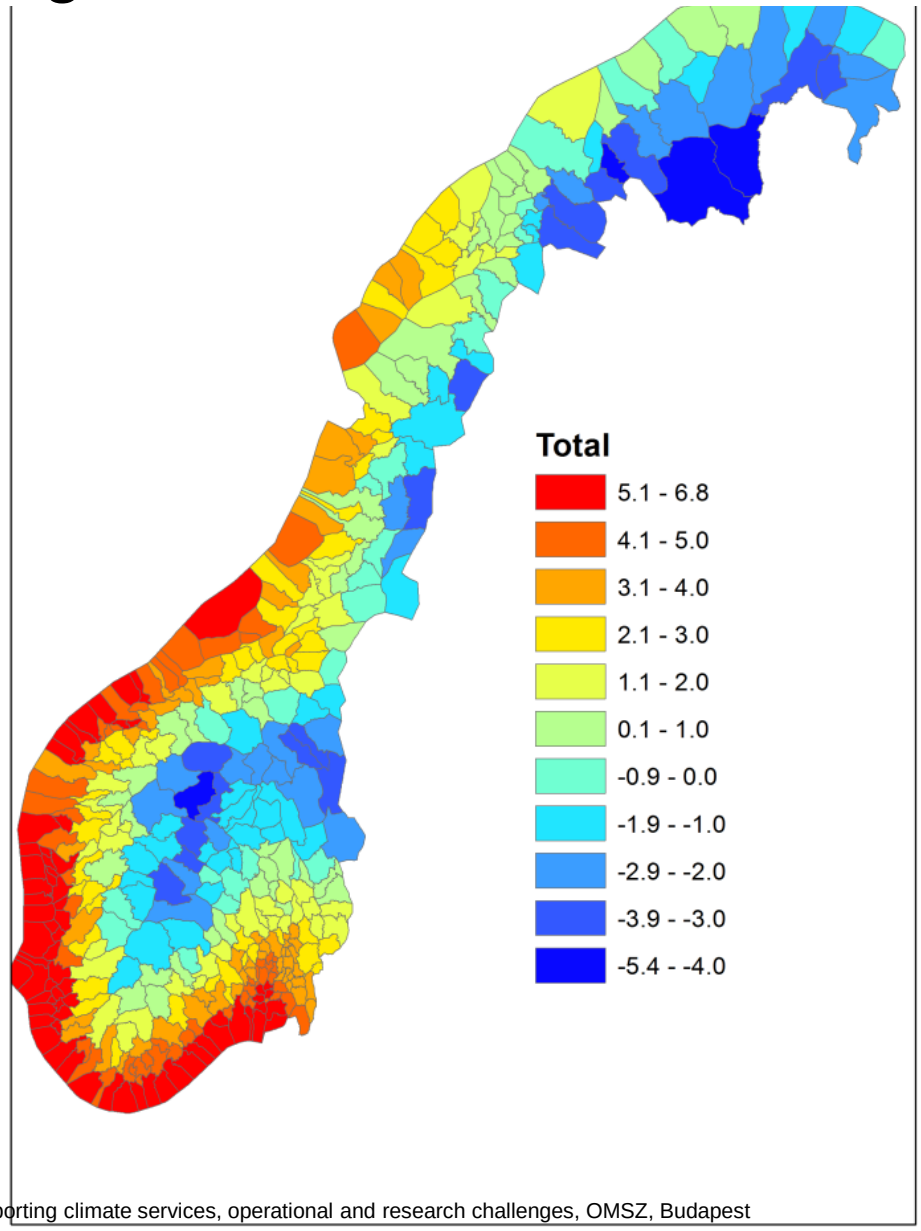
MET is developing a area averaged data set on municipality level for temperature, precipitation and snow for the purpose of societal planning.

Challenge: what is the most relevant area in a municipality?

- The entire municipality?
- The part with developed infrastructure?

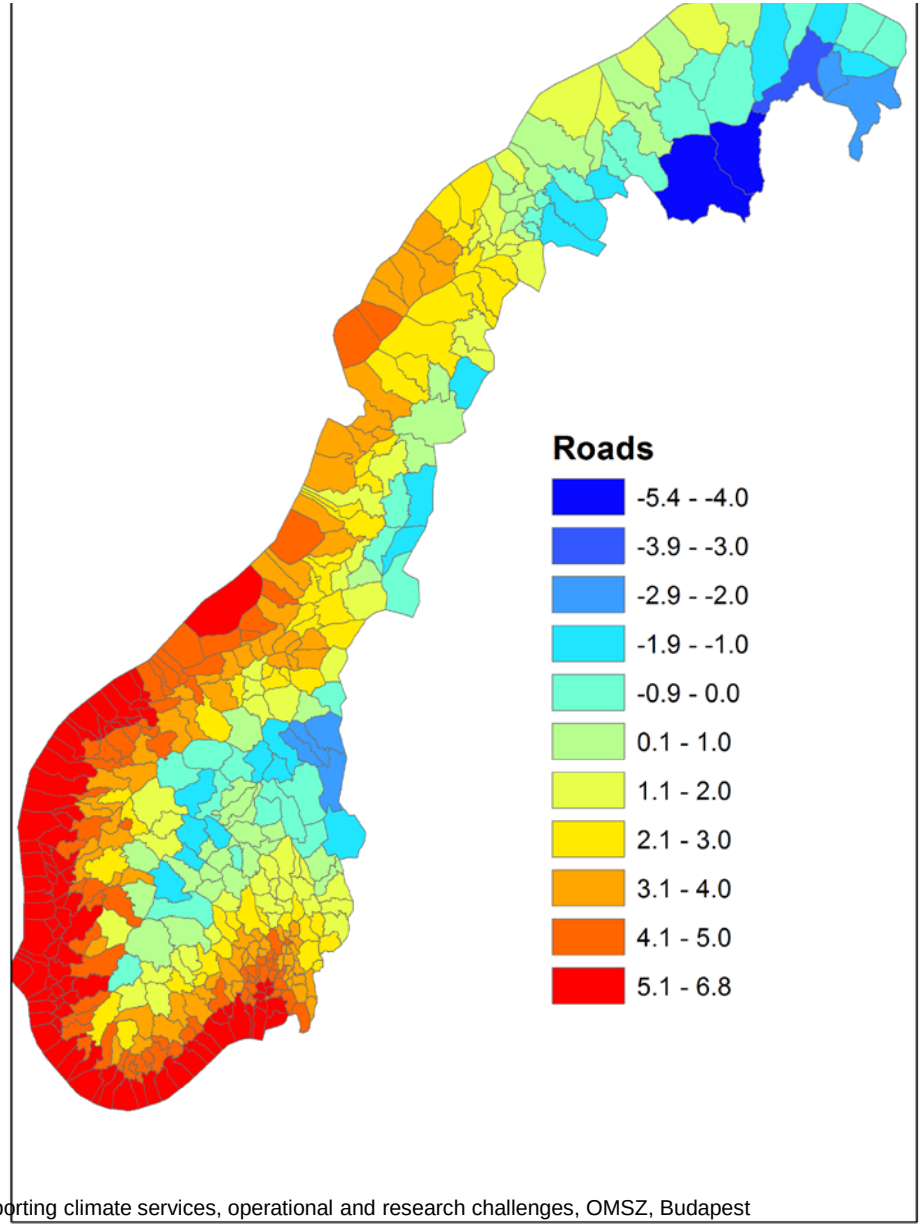
Norwegian Meteorological Institute

Mean annual temperature (1981-2010)
Covering the whole area of the municipality



Norwegian Meteorological Institute

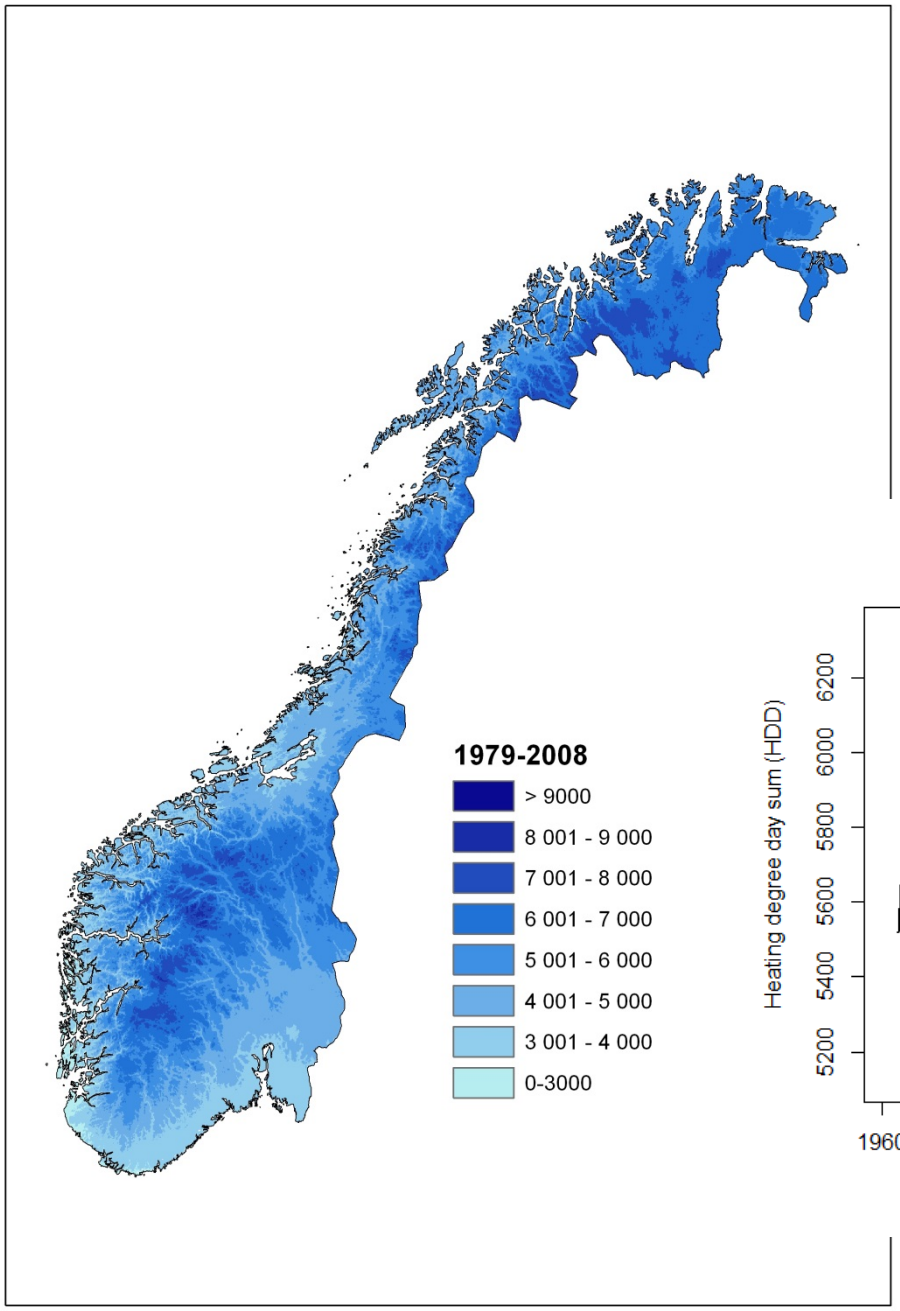
Mean annual temperature (1981-2010)
Covering the “infrastructural” area of the municipality

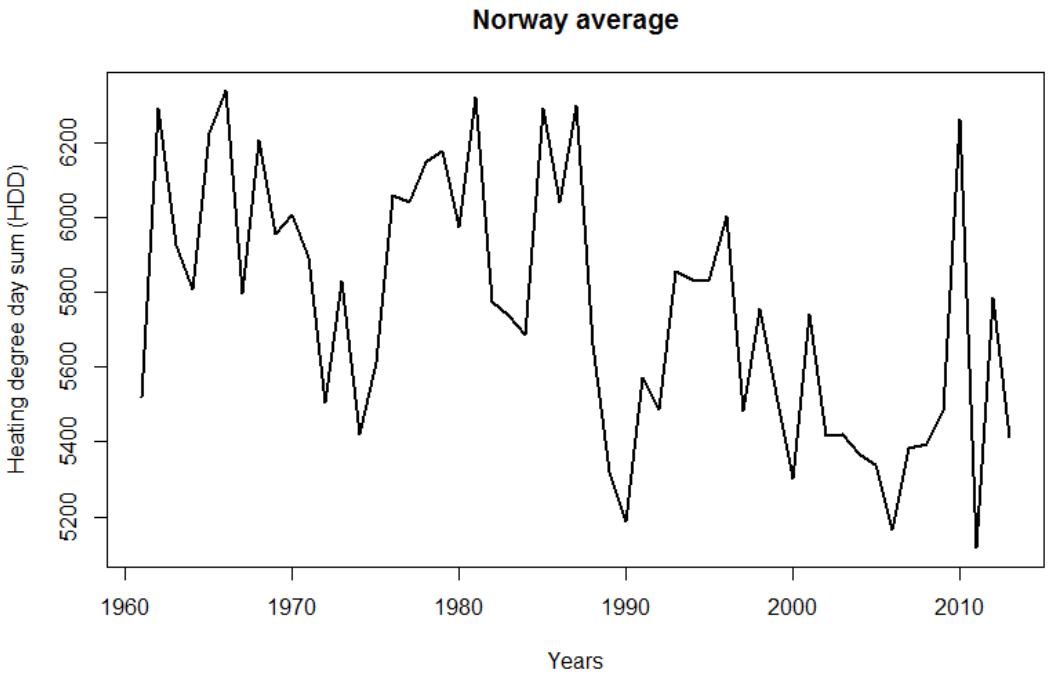


Norwegian Meteorological Institute

Heating degree days

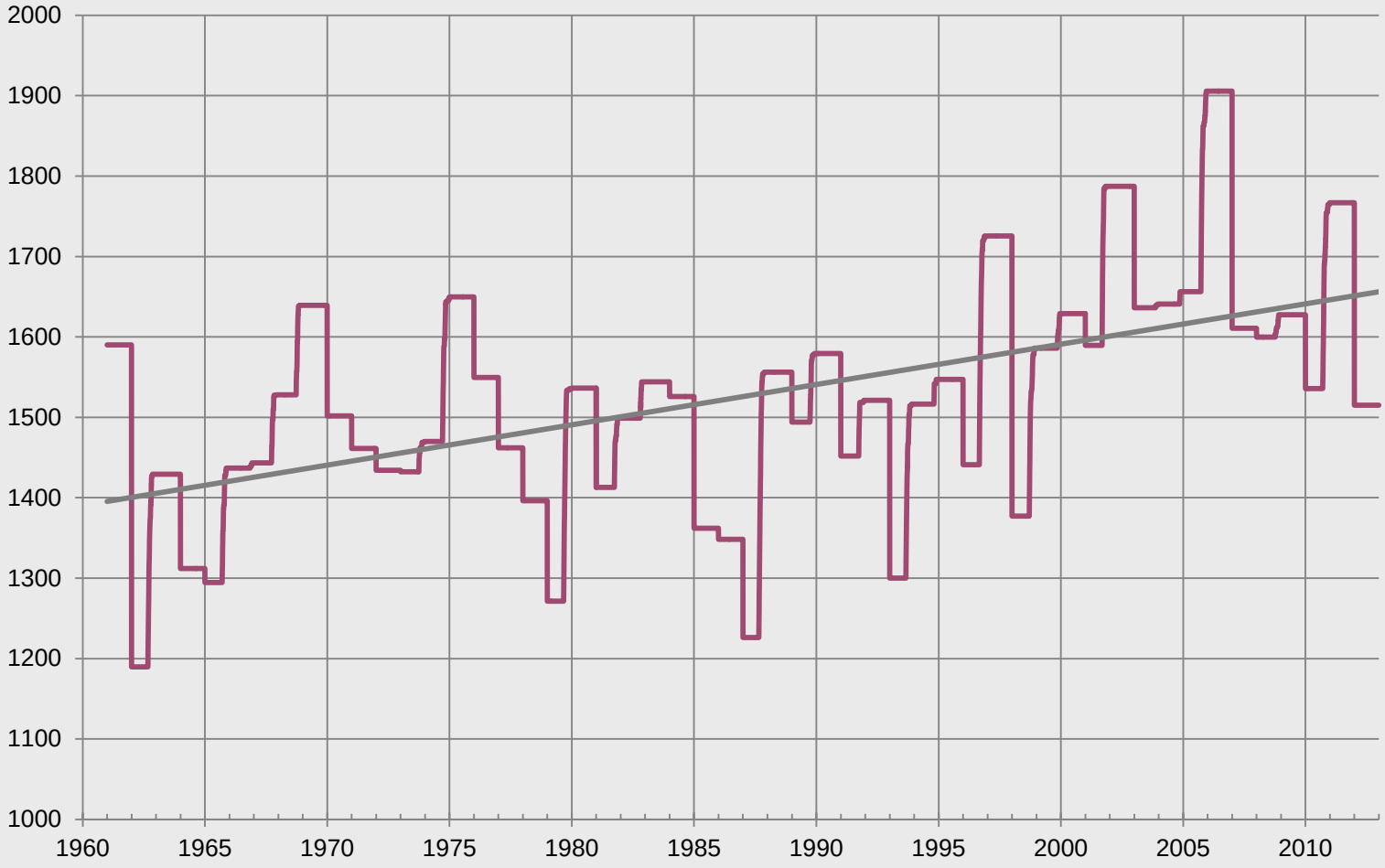
$$HDD = \sum (17 - TAM) \mid TAM < 10℃$$





Norwegian Meteorological Institute

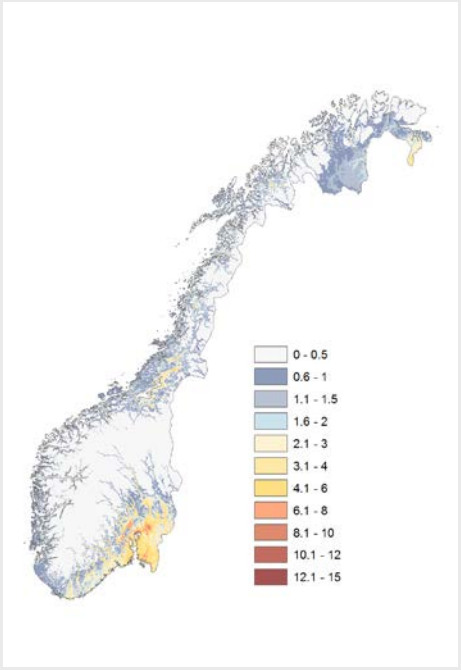
Growing degreedays in Oslo-Blindern 1961-2012



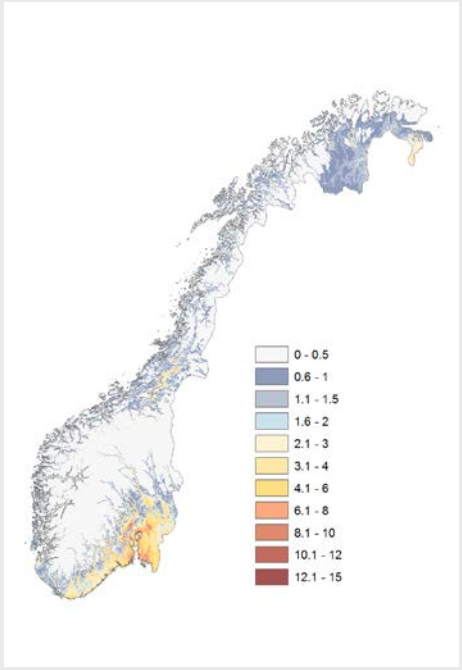
Norwegian Meteorological Institute

Days > 20 °C

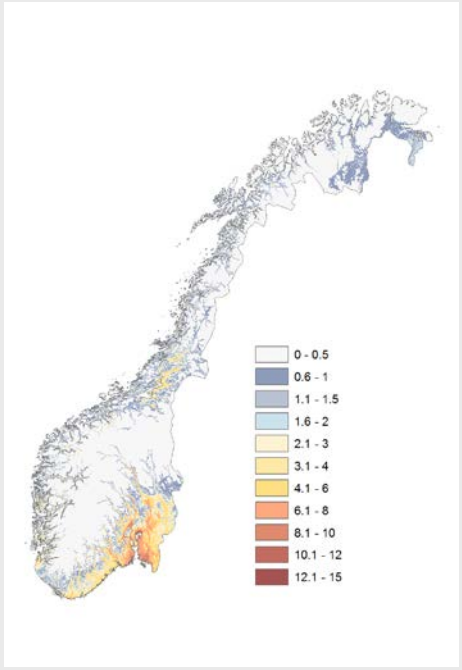
1961-1990



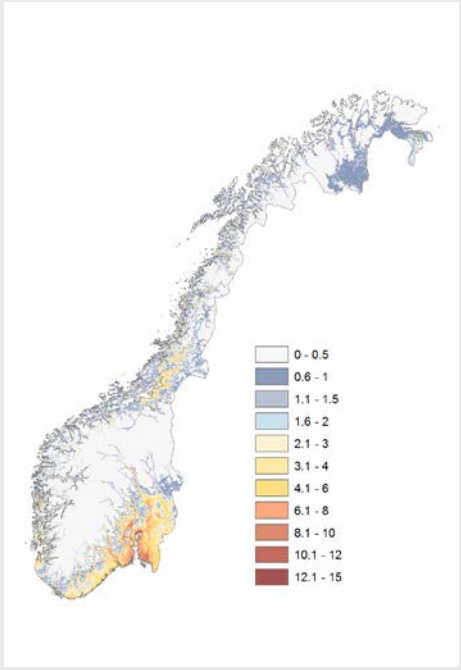
1971-2000



1981-2010

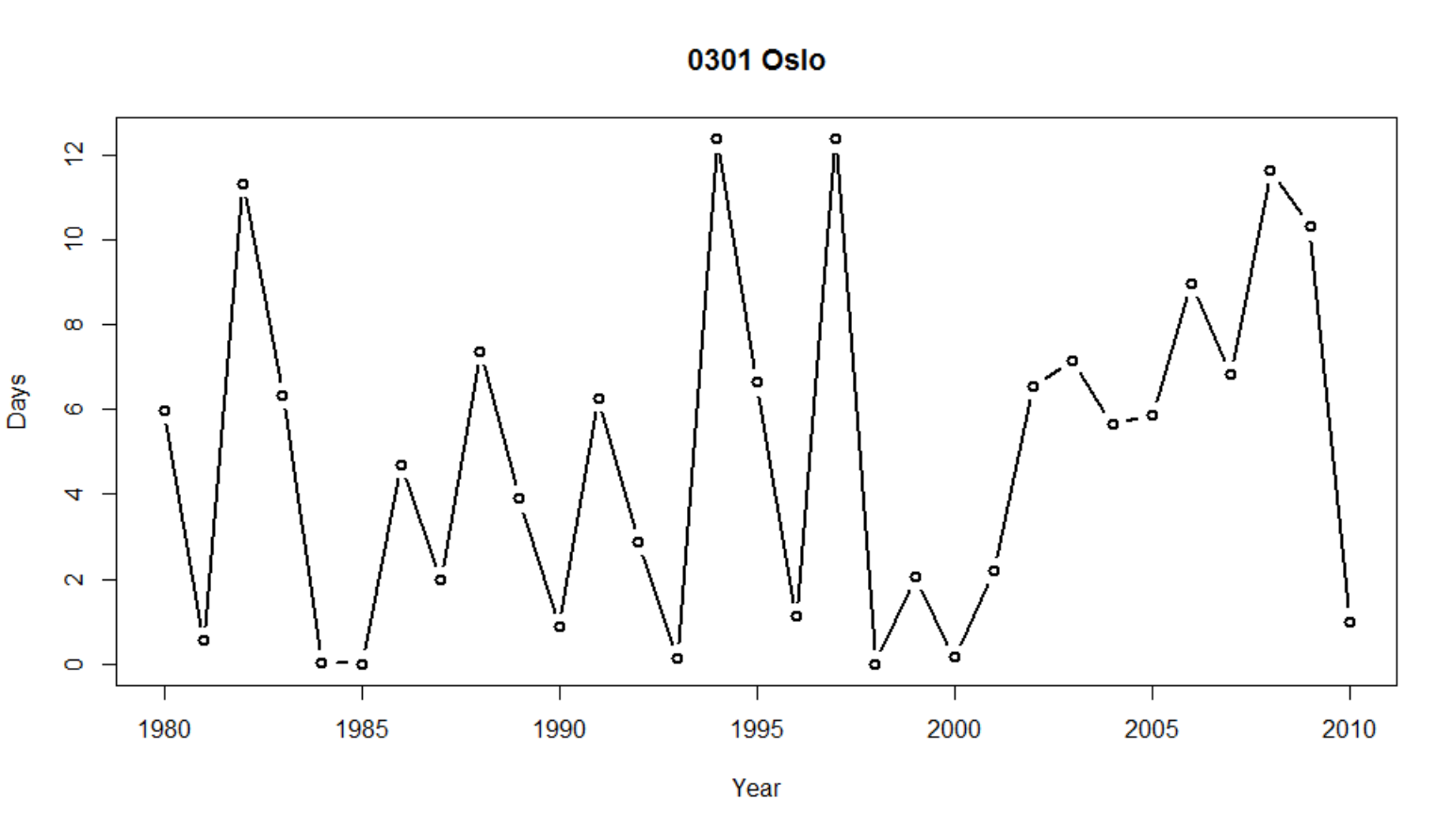


1985-2014



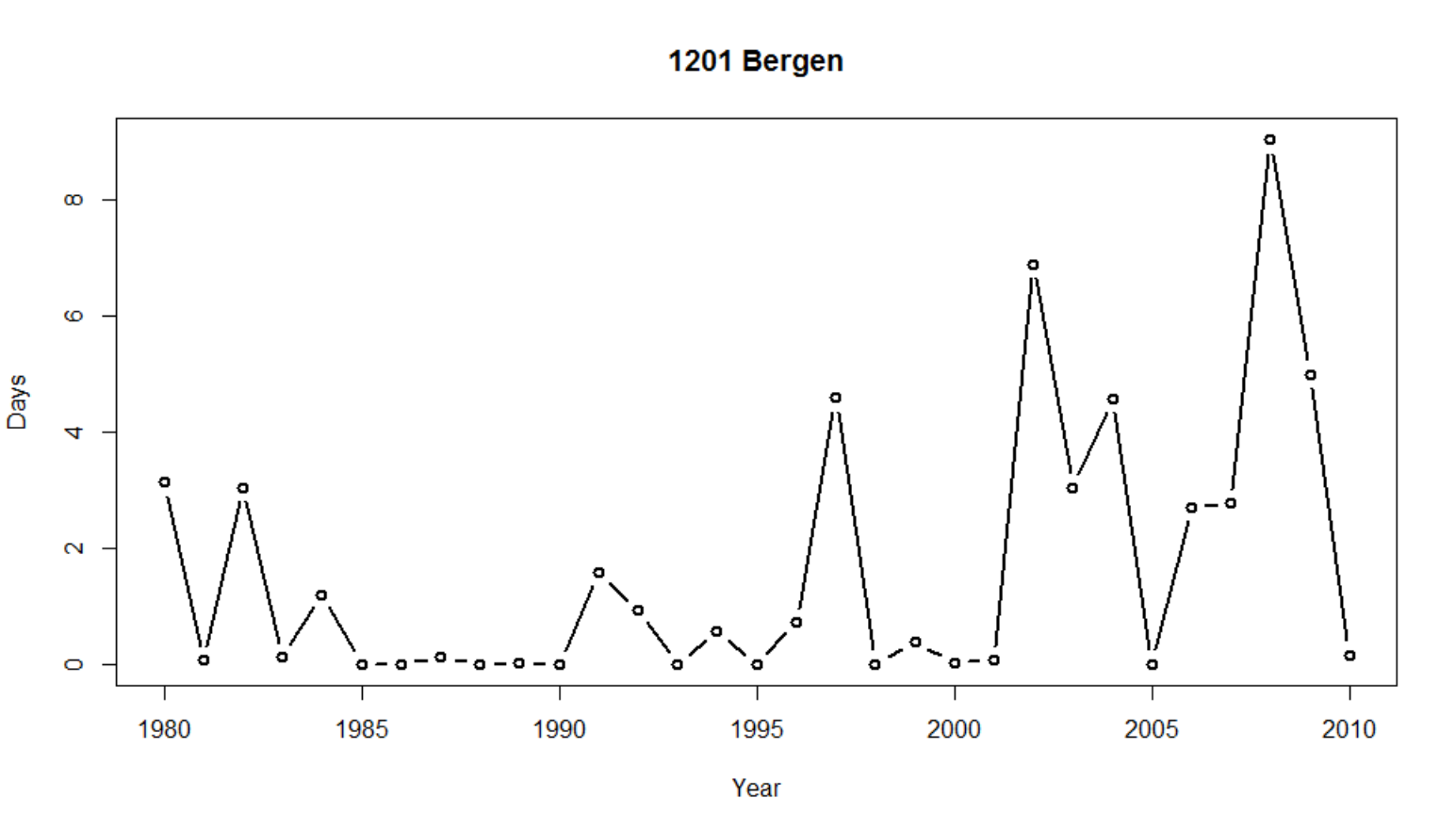
Norwegian Meteorological Institute

Days > 20°C



Norwegian Meteorological Institute

Days > 20°C



Norwegian Meteorological Institute

Norwegian Meteorological Institute

Observation gridding

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)

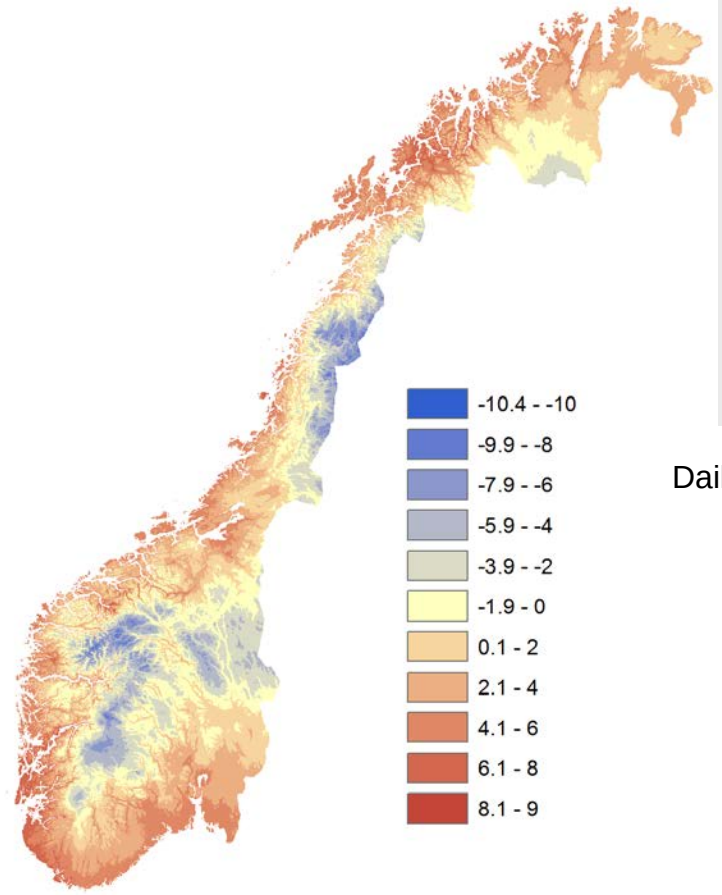
- Precipitation 1h (RR_1)
- Precipitation 3h (based on hourly observations)
- Temperature hourly (TA)

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

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

Norwegian Meteorological Institute

Daily mean temperature 16.March 2015

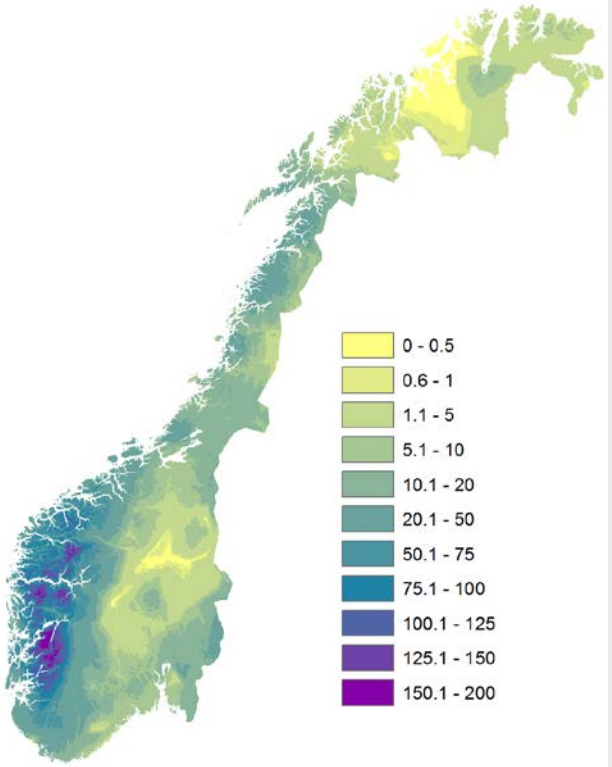


Klimagrid 1.1

Temperature and precipitation

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

Daily precipitation 29.October 2014



Norwegian Meteorological Institute

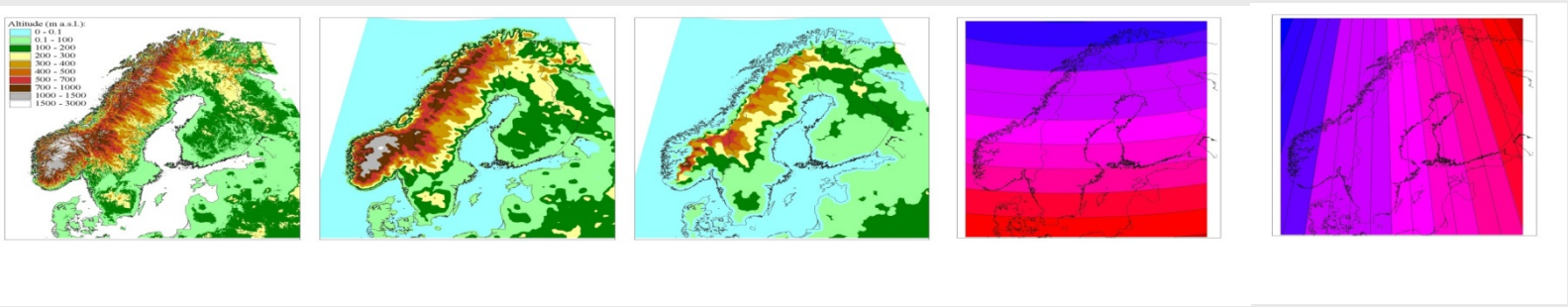
Klimagrid v1.1 Temperature

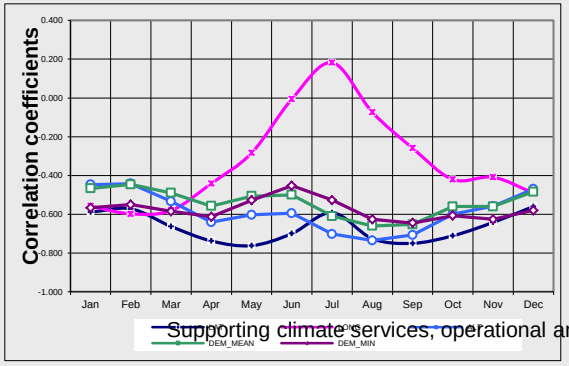
- Residual interpolation:

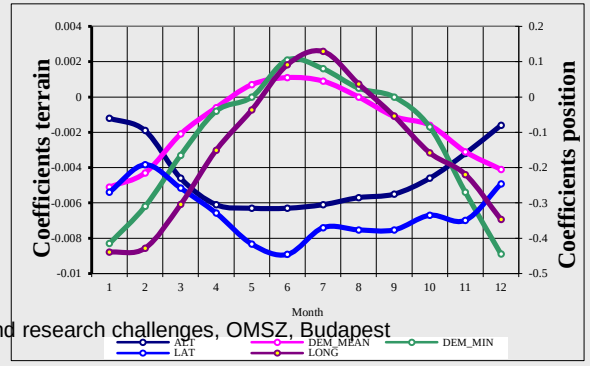
$$\hat{t}(u_0) = \sum_{i=1}^{n} \lambda_i t(u_i) + \{\alpha_0 + \alpha_1\beta_1(u_0) + \alpha_2\beta_2(u_0) + \ldots\ldots + \alpha_m\beta_m(u_0)\}$$

Kriging
(or any spatial interpolation method)

External trend/drift
(linear regression)

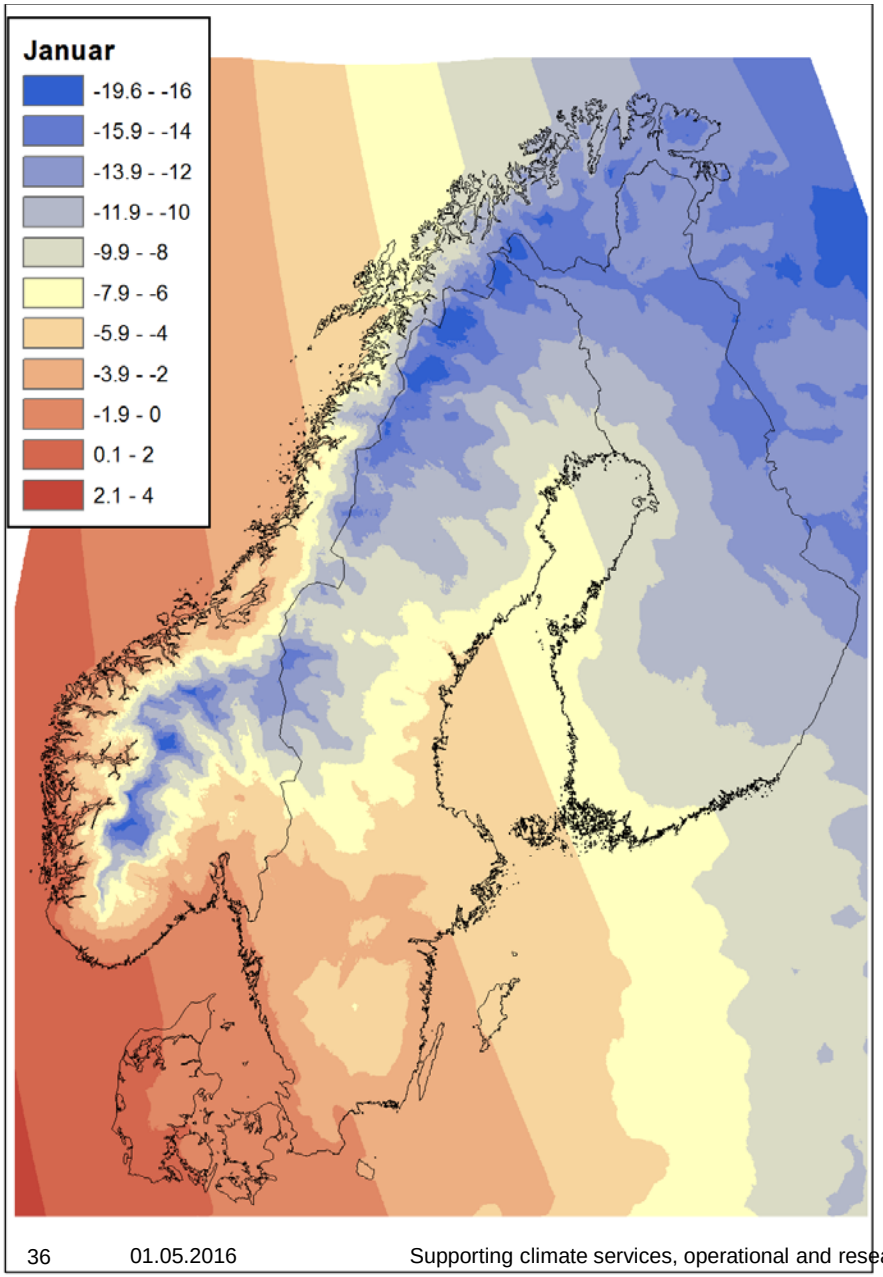


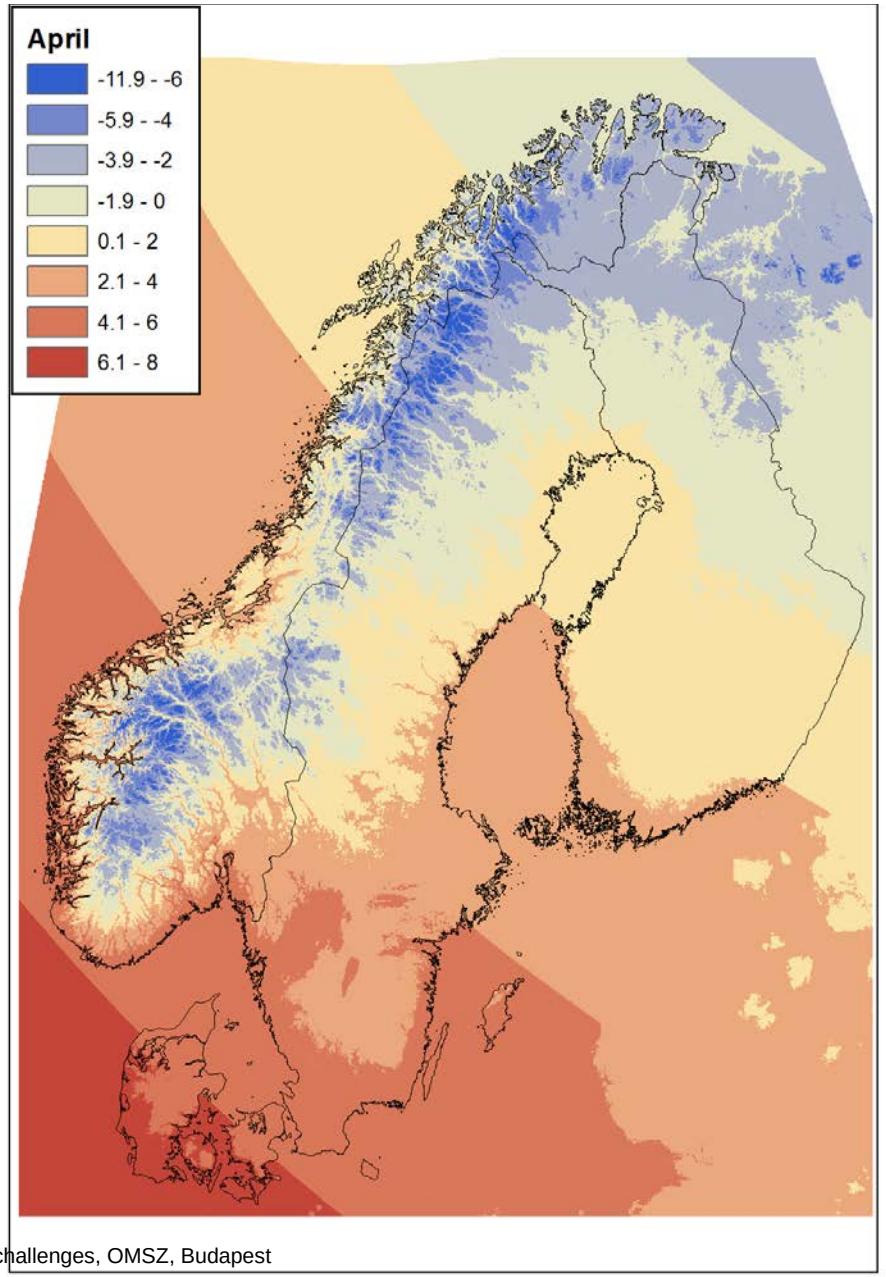




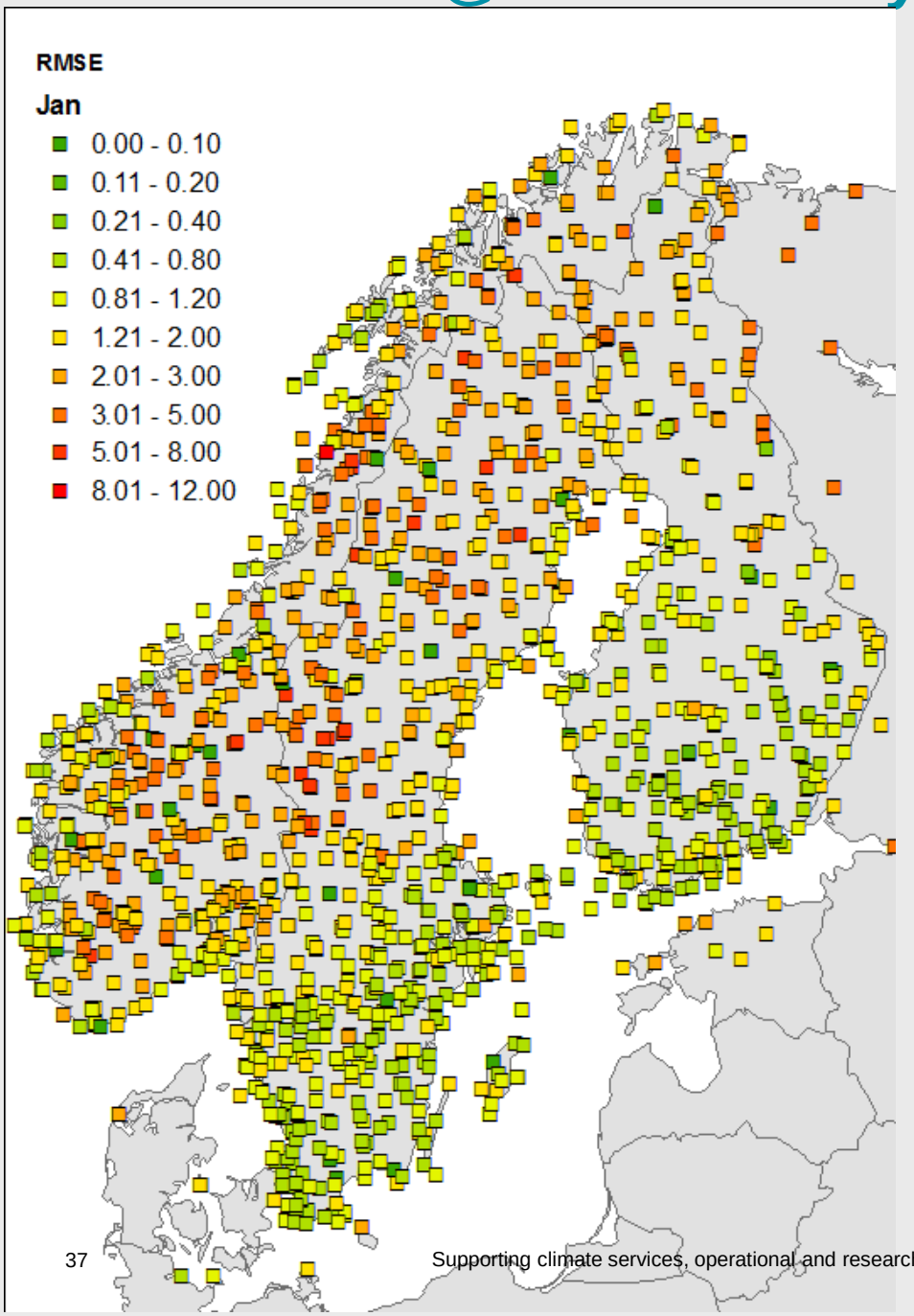
Norwegian Meteorological Institute

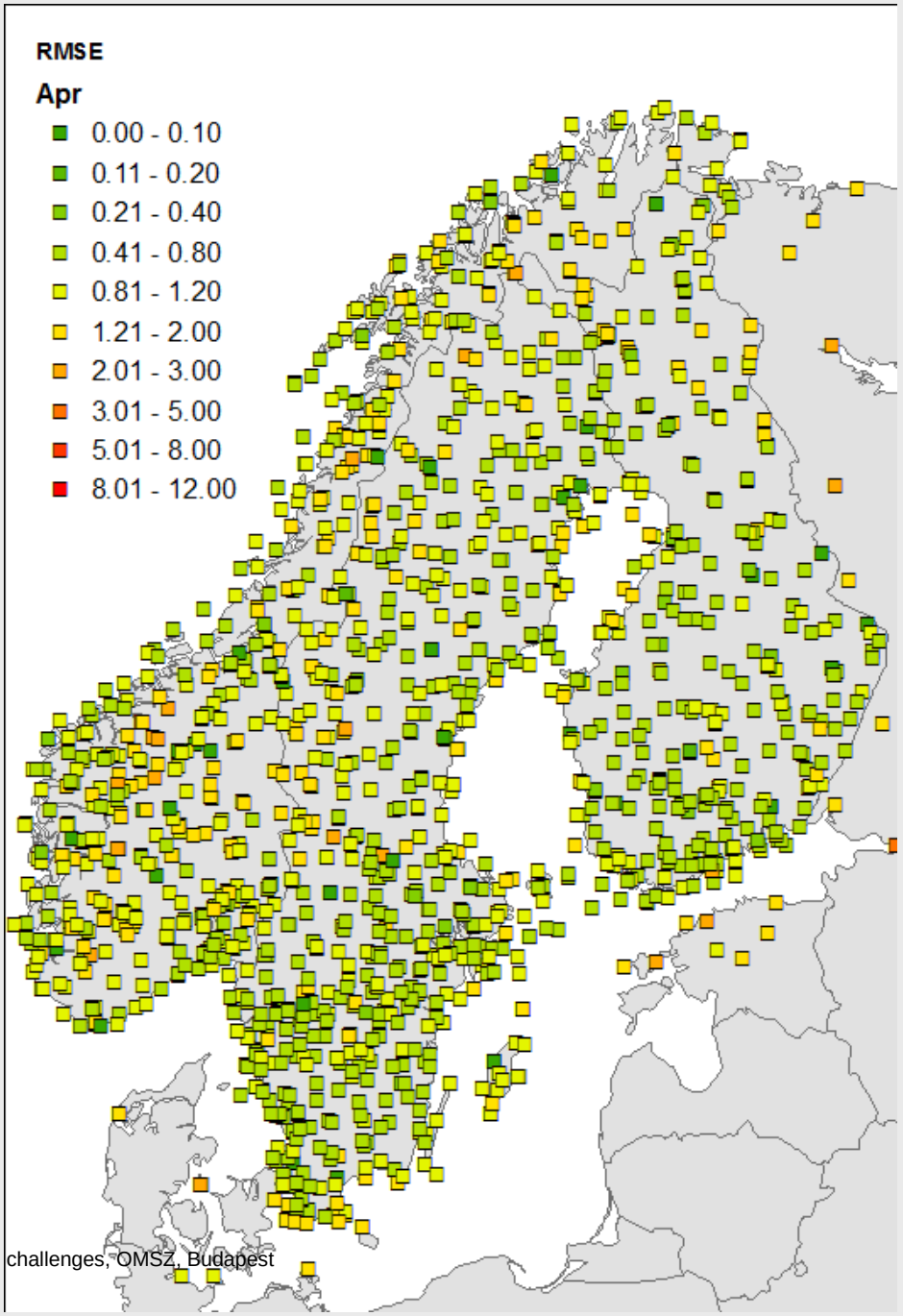
Trend ➔ climatological first guess





NGCD.RK @ MET Norway – TEMP1d - Evaluation

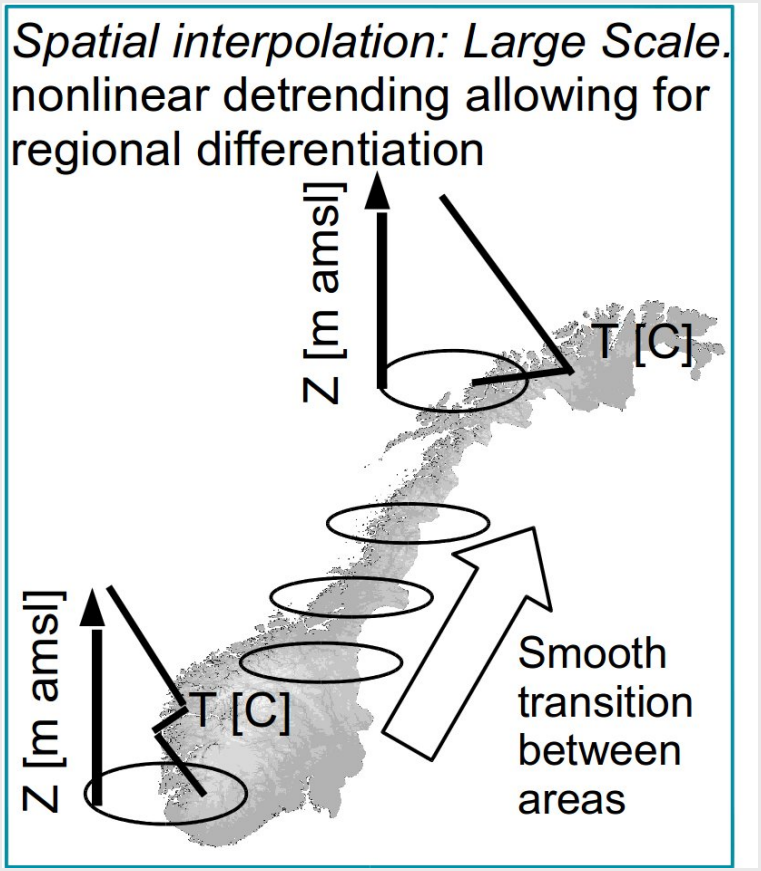




Klimagrid 2.0
TEMP1d: OI

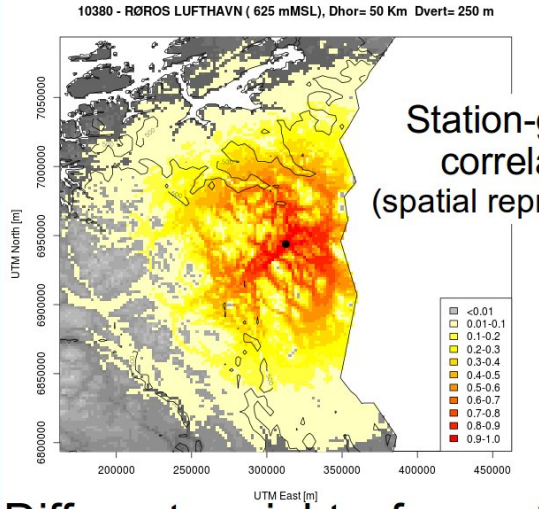
Large(coarser) scale trend estimation

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



+

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



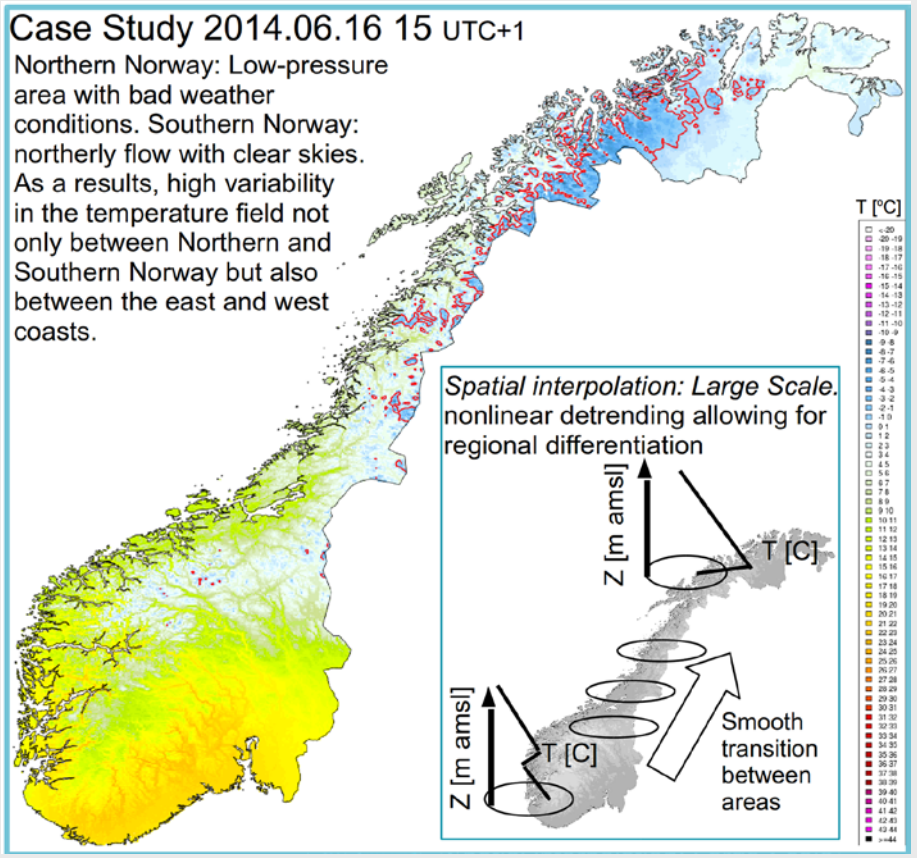
Different weights for vertical and horizontal distances.

OI introduces the Local(finer) scale

Temperature

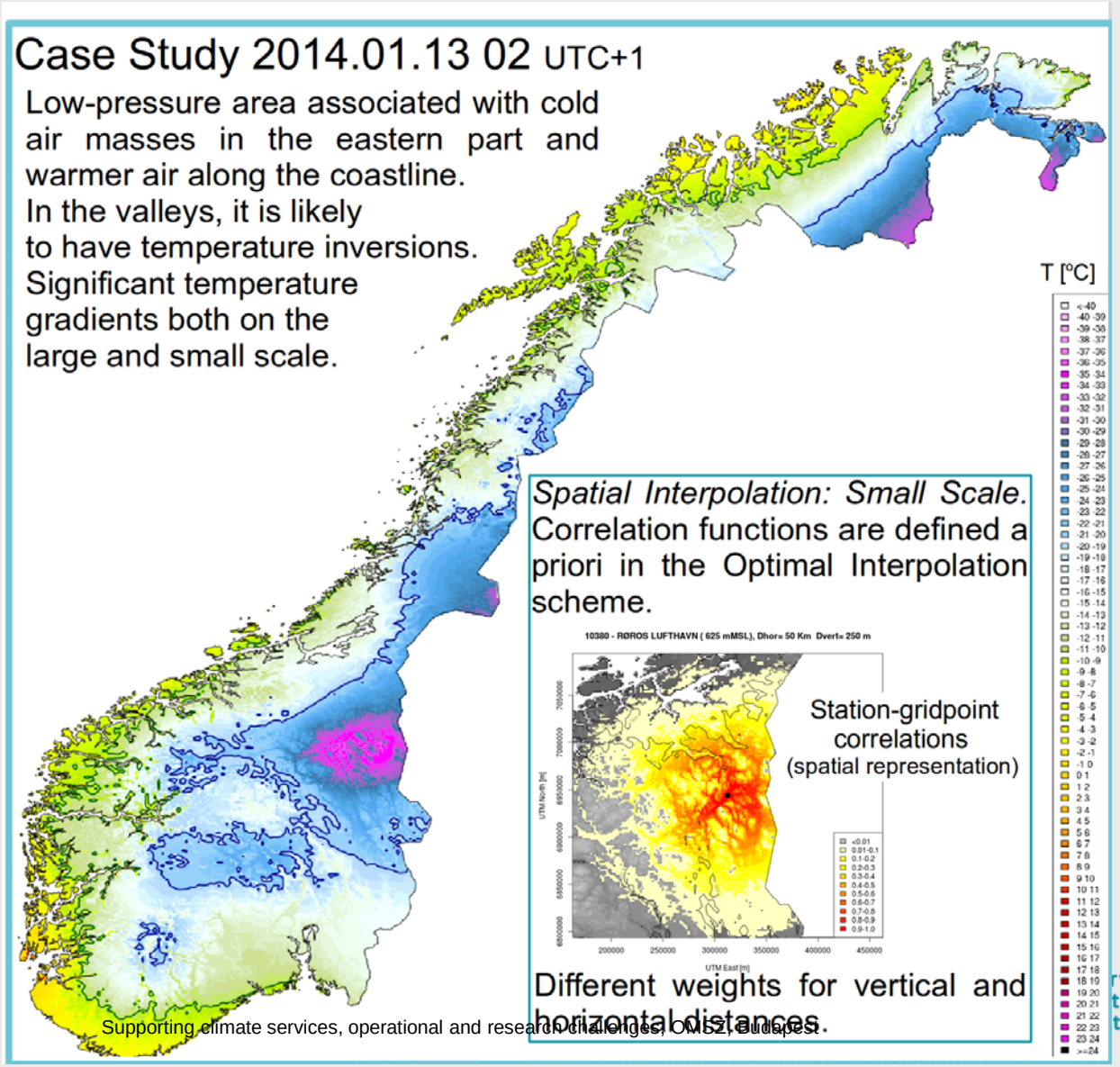
- Spatial interpolation method is the same both for **hourly** and **daily** (in the future, it is possible that a post-processing of 24 hourly temperature fields will be used a first guess for the daily spatial interpolation)

- Spatial Interpolation method: hourly temperature – Large scale after de-trending



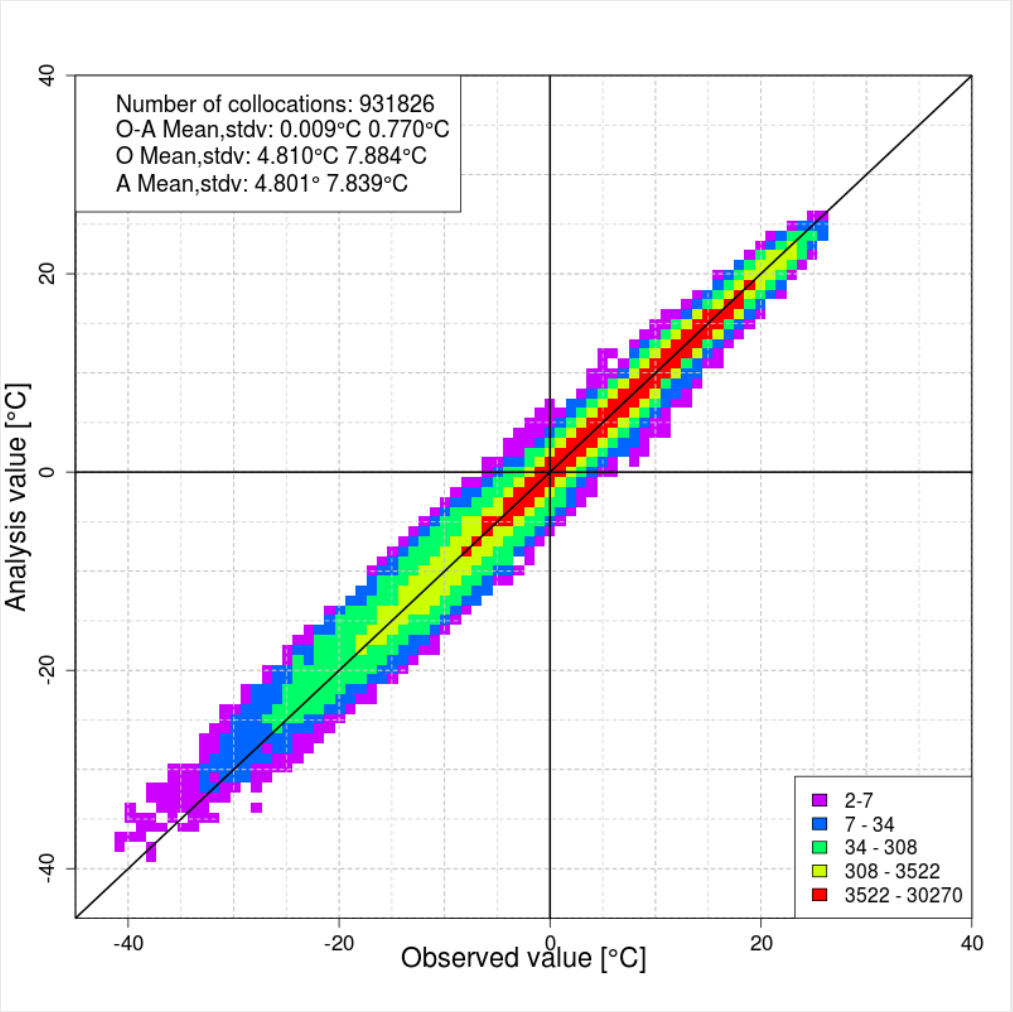
Norwegian Meteorological Institute

Temperature: local scale

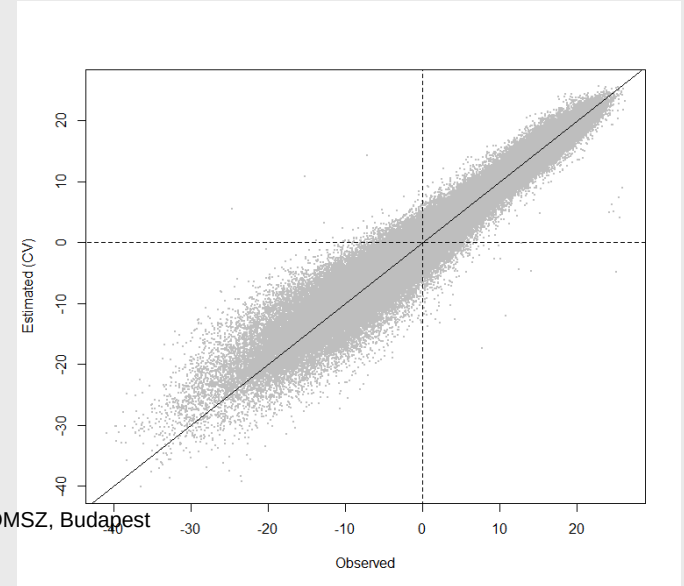


rwegian
teorological
titute

Uncertainty estimate at station locations

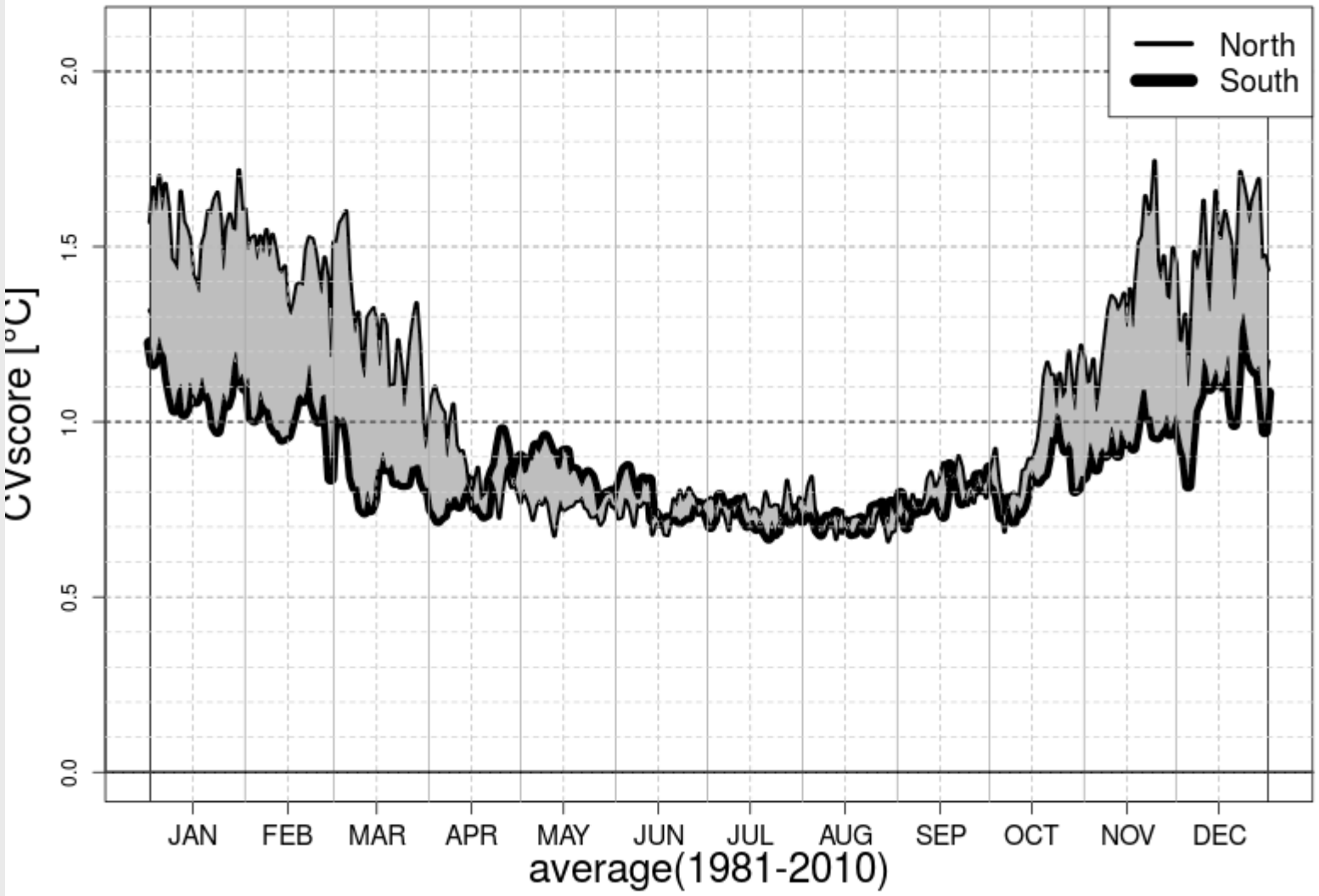


10-year period considered (2003.09 – 2014.09). The number of collocations considered is 931826 (i.e. number of pairs (predicted, observed)). The Figure is a sort a 3D histogram. Take for instance the point
(-40,35)
The figure shows that only 2-7 pairs have this values.
Comments: predictions are close to the observations (see the red area), the dispersion increases for lower T values.



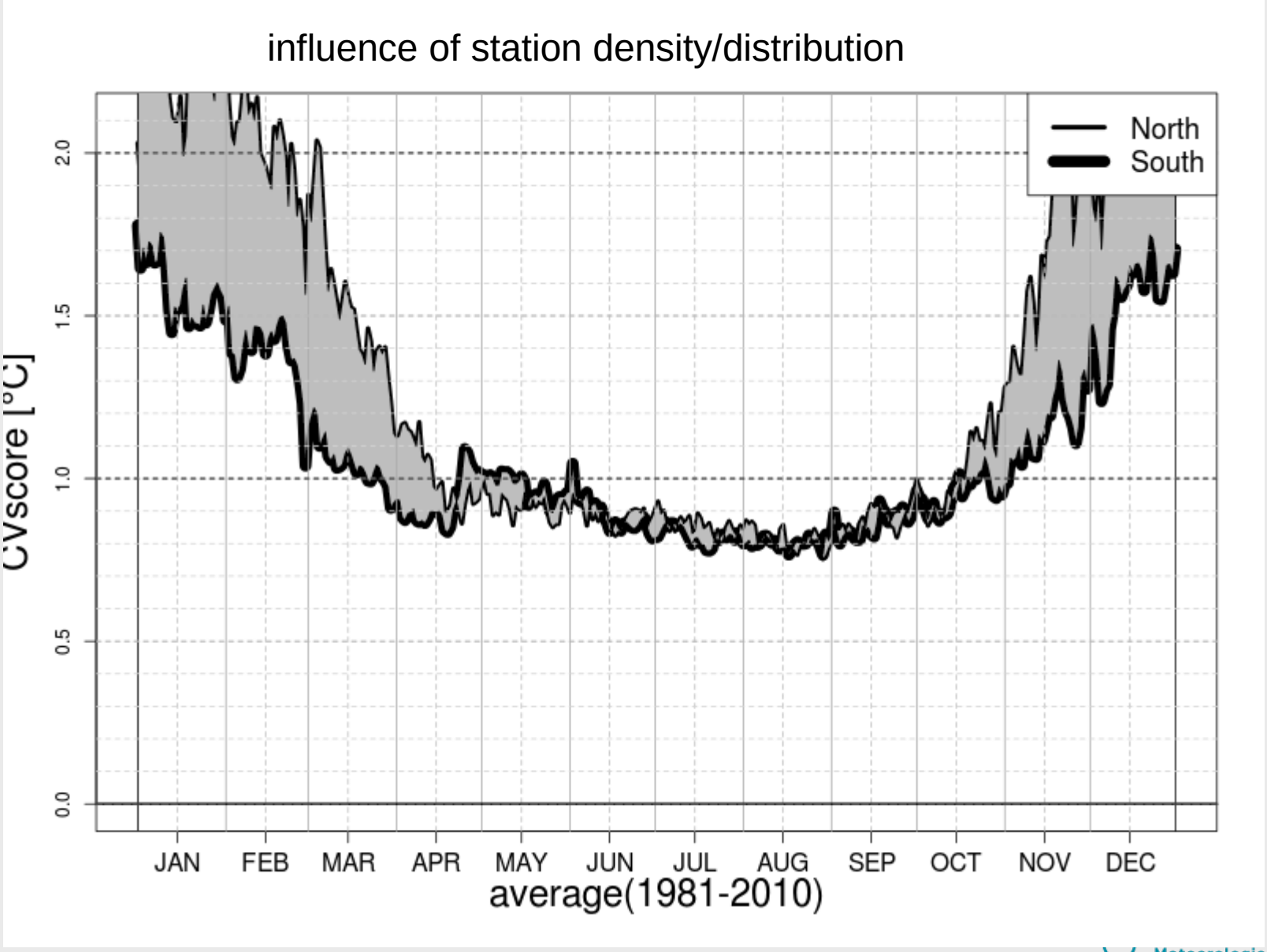
NGCD.OI @ MET Norway – TEMP1d - Evaluation

influence of station density/distribution



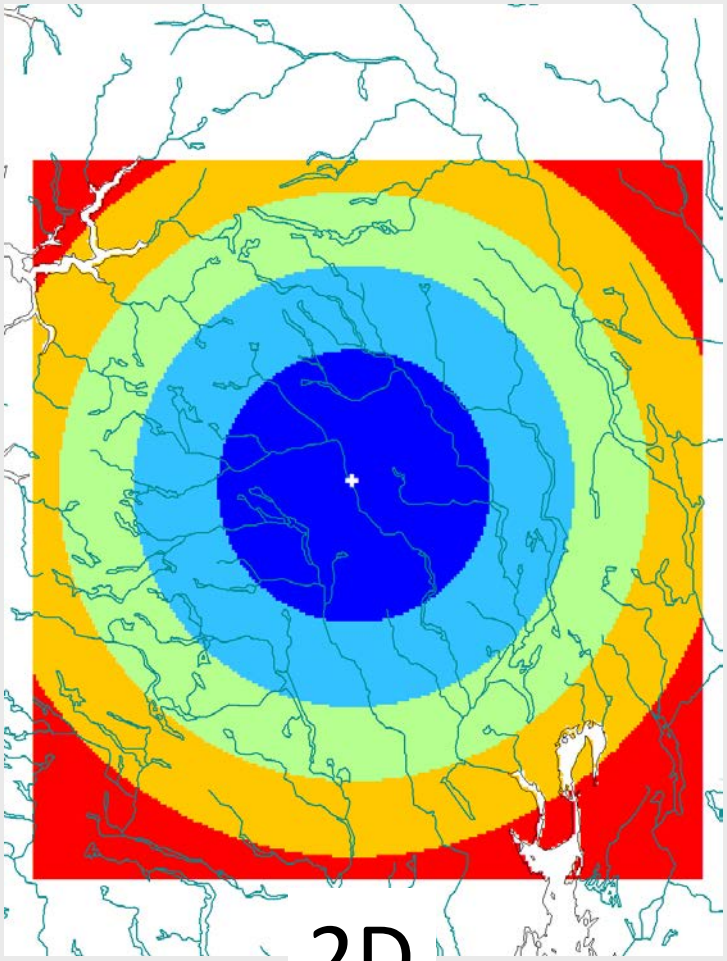
Meteorological Institute

NGCD.RK @ MET Norway – TEMP1d - Evaluation



Meteorological Institute

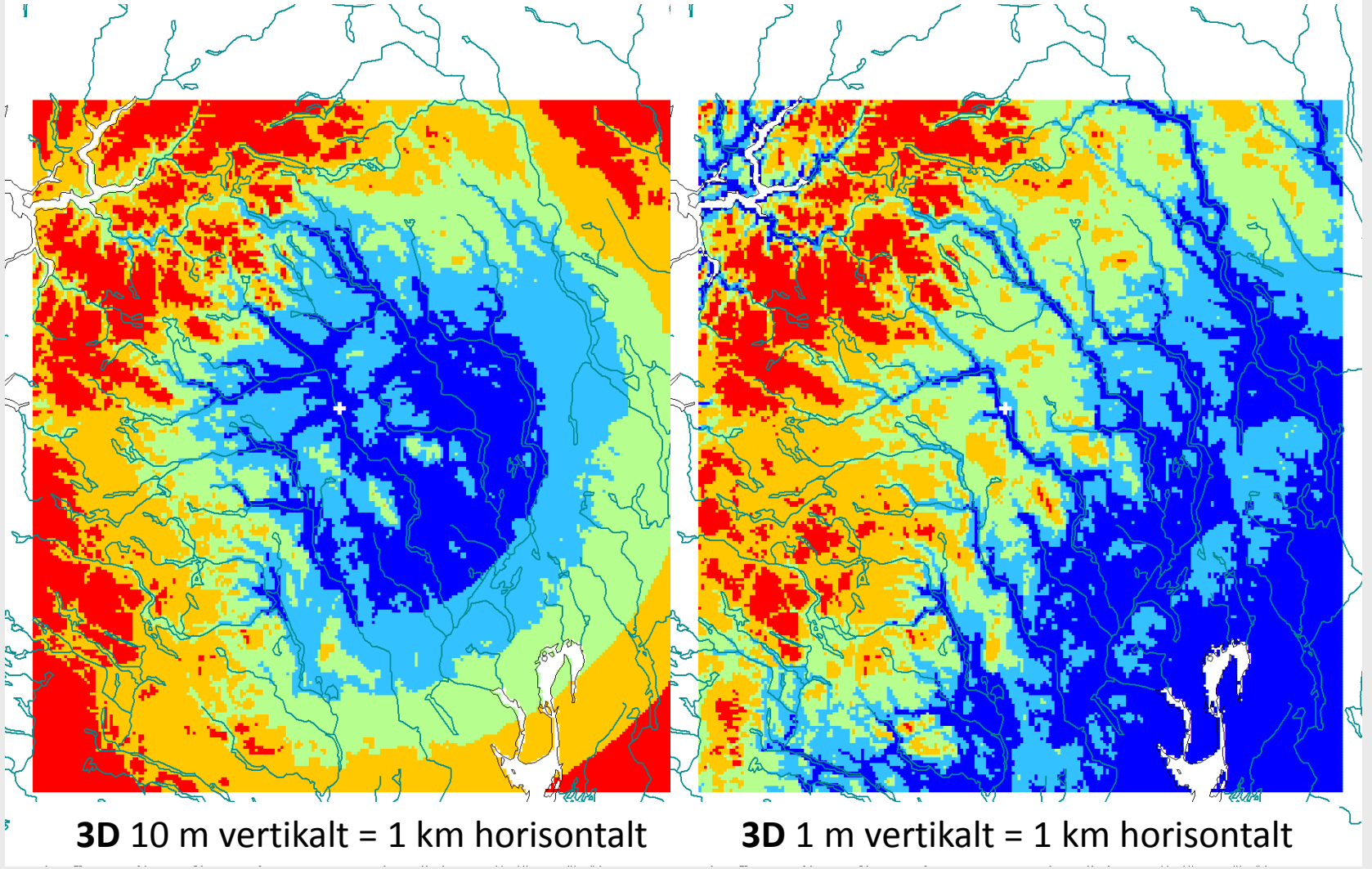
Distances - Euclidean



2D

Norwegian Meteorological Institute

Distances – non-Euclidean



3D 10 m vertikalt = 1 km horisontalt

3D 1 m vertikalt = 1 km horisontalt

Norwegian Meteorological Institute

Concept

- Include 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

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

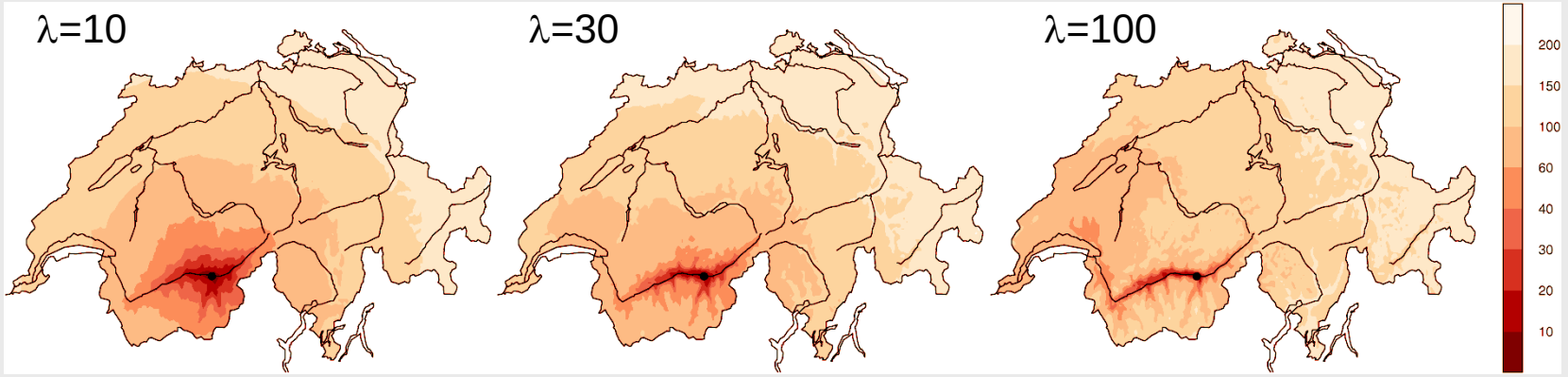
  - Different k's are applied (λ's in examples from Switzerland).
  - Compared to operational method (SN)

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

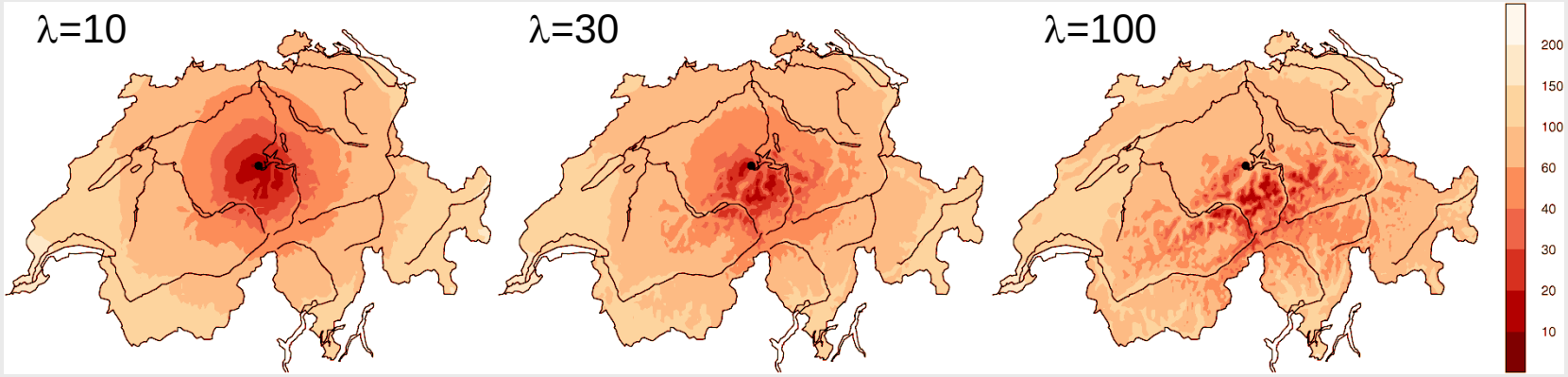
$$h = \sqrt{x^2 + y^2 + \sum_{i=1}^{n} (\kappa_i Z_i)^2}$$

Non-Eucledian Spatial Representativity

Distance from Visp in km (valley-floor)

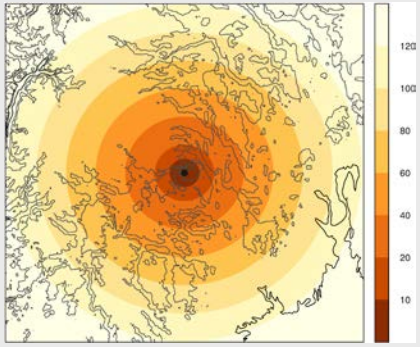


Distance from Pilatus in km (mountain peak)

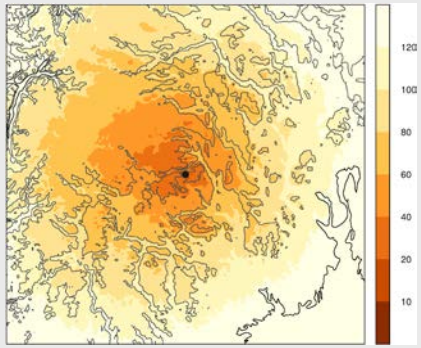


Frei 2014 (Int. J. Climatol.)

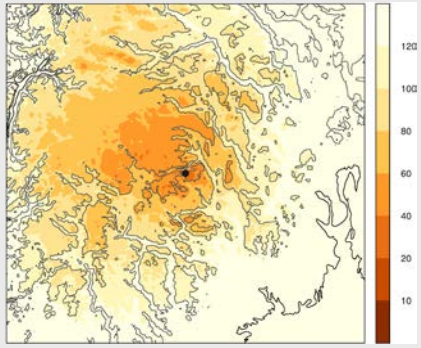
Norwegian Meteorological Institute



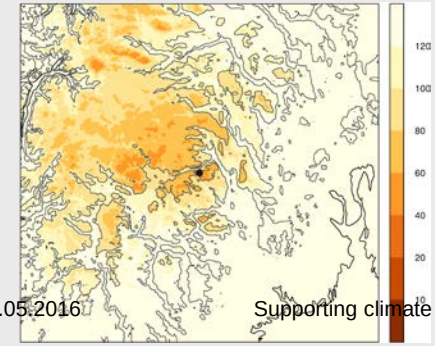
λ=0



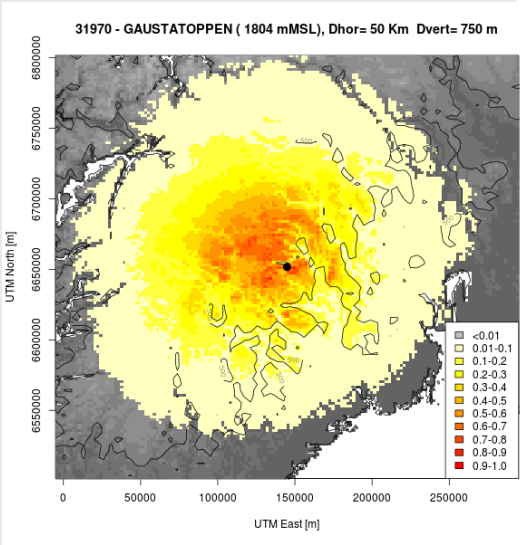
λ=50

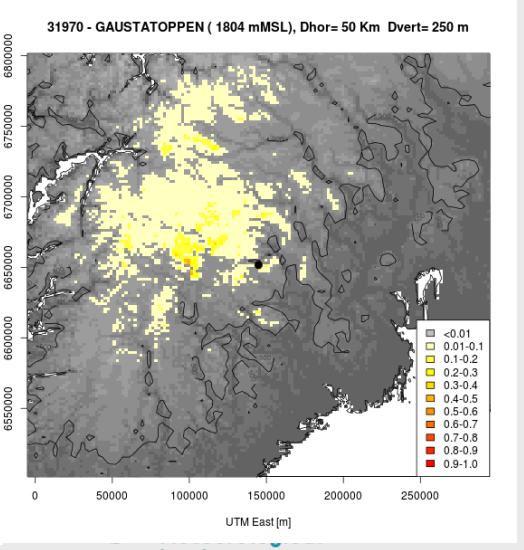


λ=100



λ=200

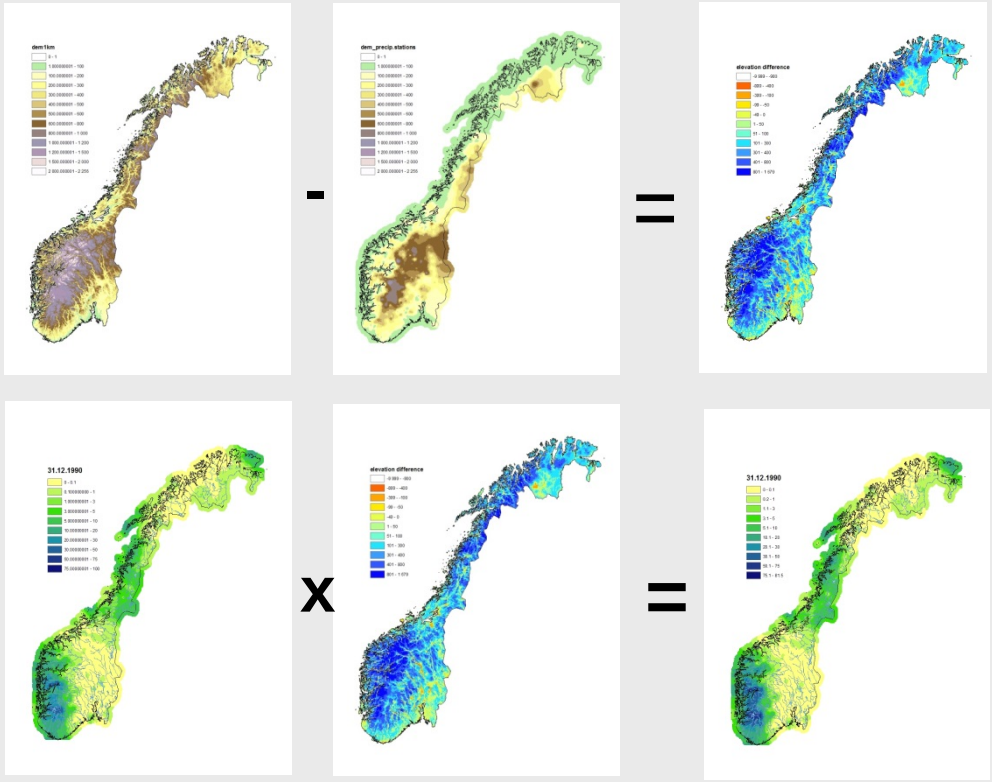


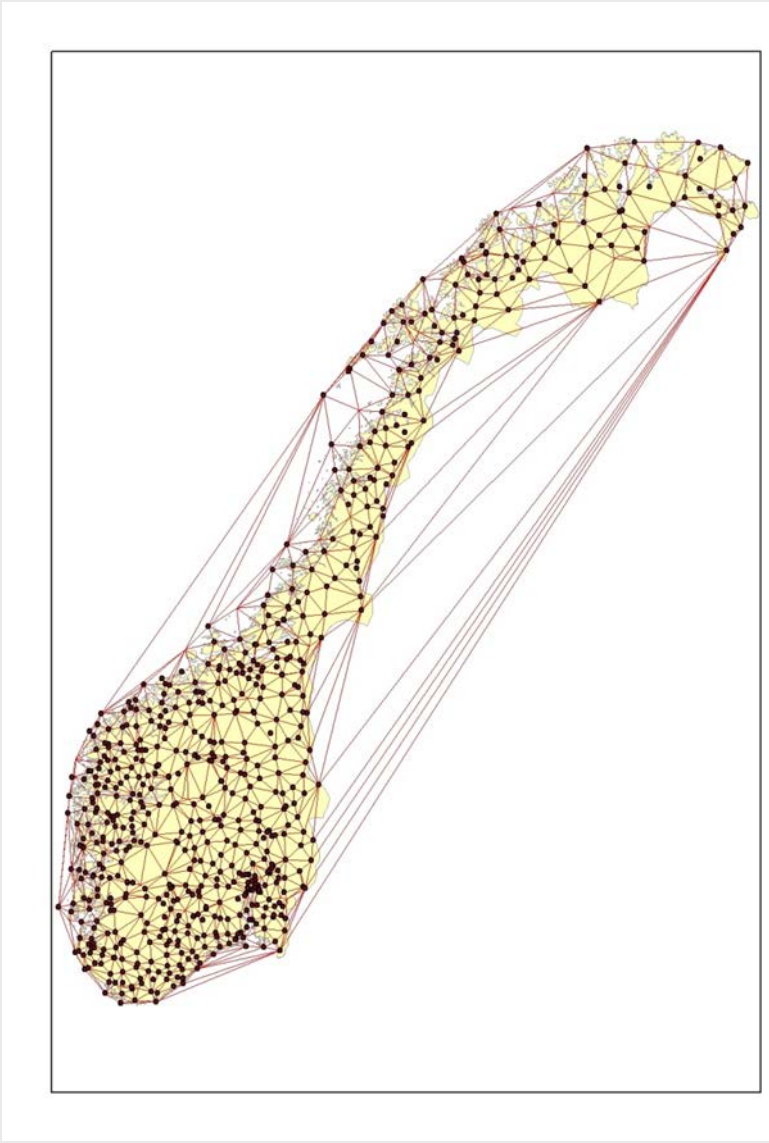


Institute

Precipitation v1.1

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





Norwegian Meteorological Institute

Precip v.2.0 - procedure

1. Retrieve observations from Climate database (DQC)
2. Identification of Events
   a) Precipitation yes/no distinction (gridpoints)
   b) Contiguous Precipitation Areas (CPAs) identification and labeling
3. Iterative loop over Events
   - Multiscale Optimal Interpolation
     - Event coarser scale

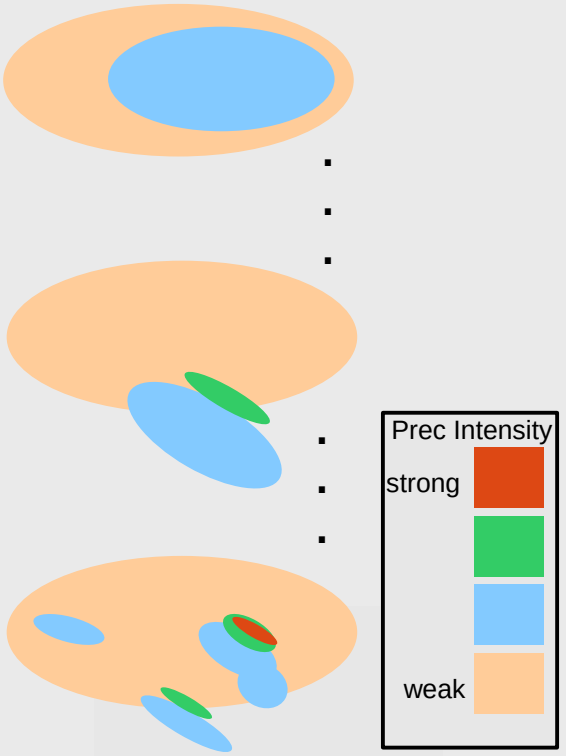
Cascade of spatial scales: from coarser to finer levels

- Event finer scale

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

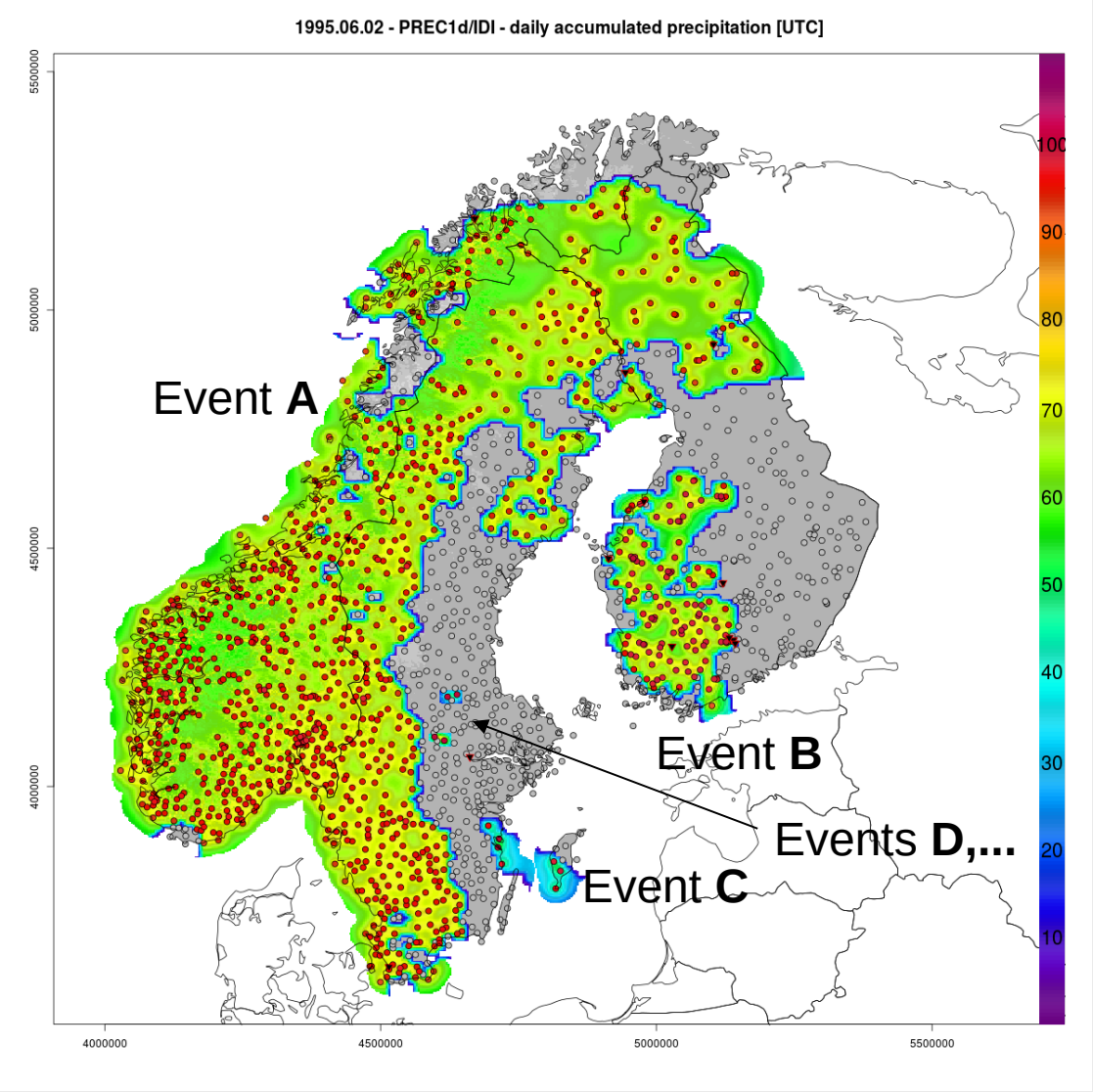
information

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



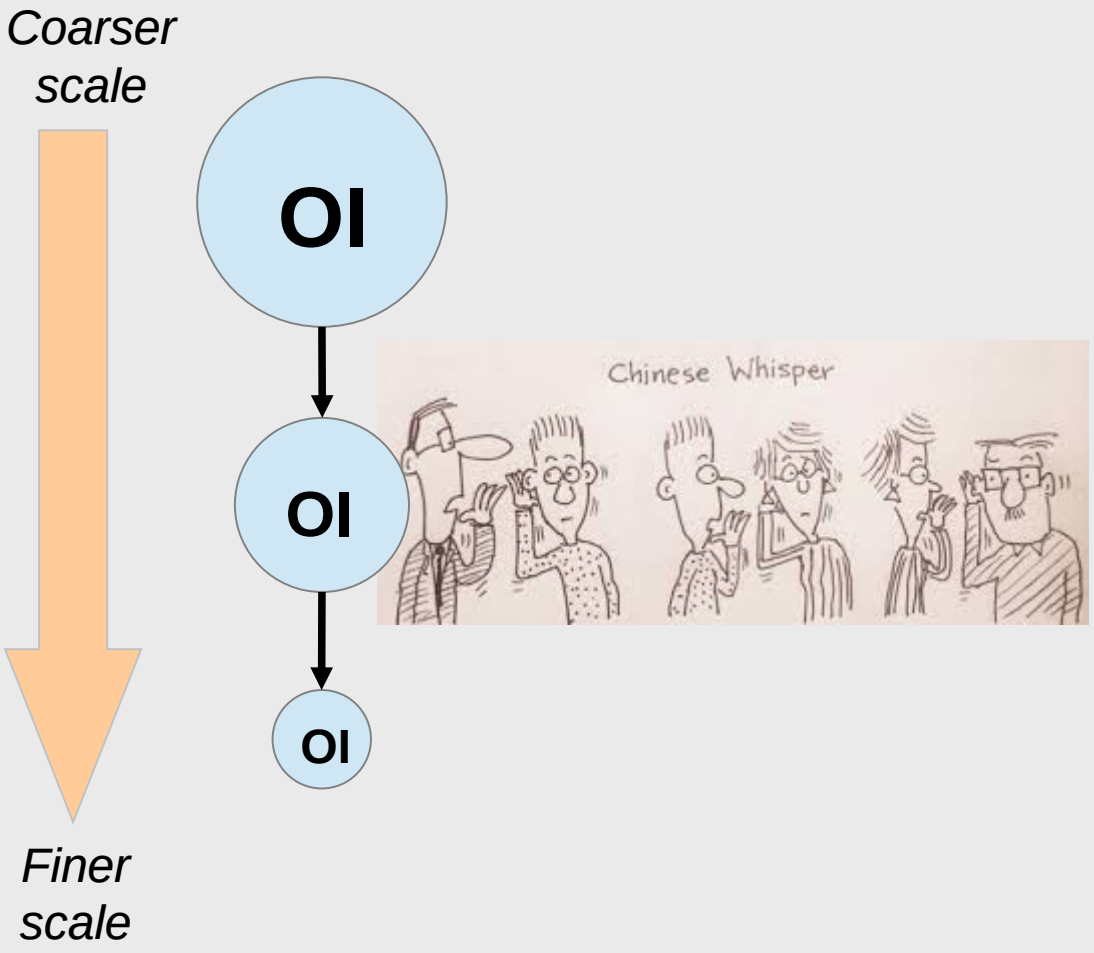
Spatial Interpolation Method based on Multi-scale Optimal Interpolation (Prec)

Step 0: Identification of Precipitation Events (Observed Areas of Precipitation)
(given the Station distribution)



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

Given a single Event, the spatial interpolation is based on an *iterative* process:



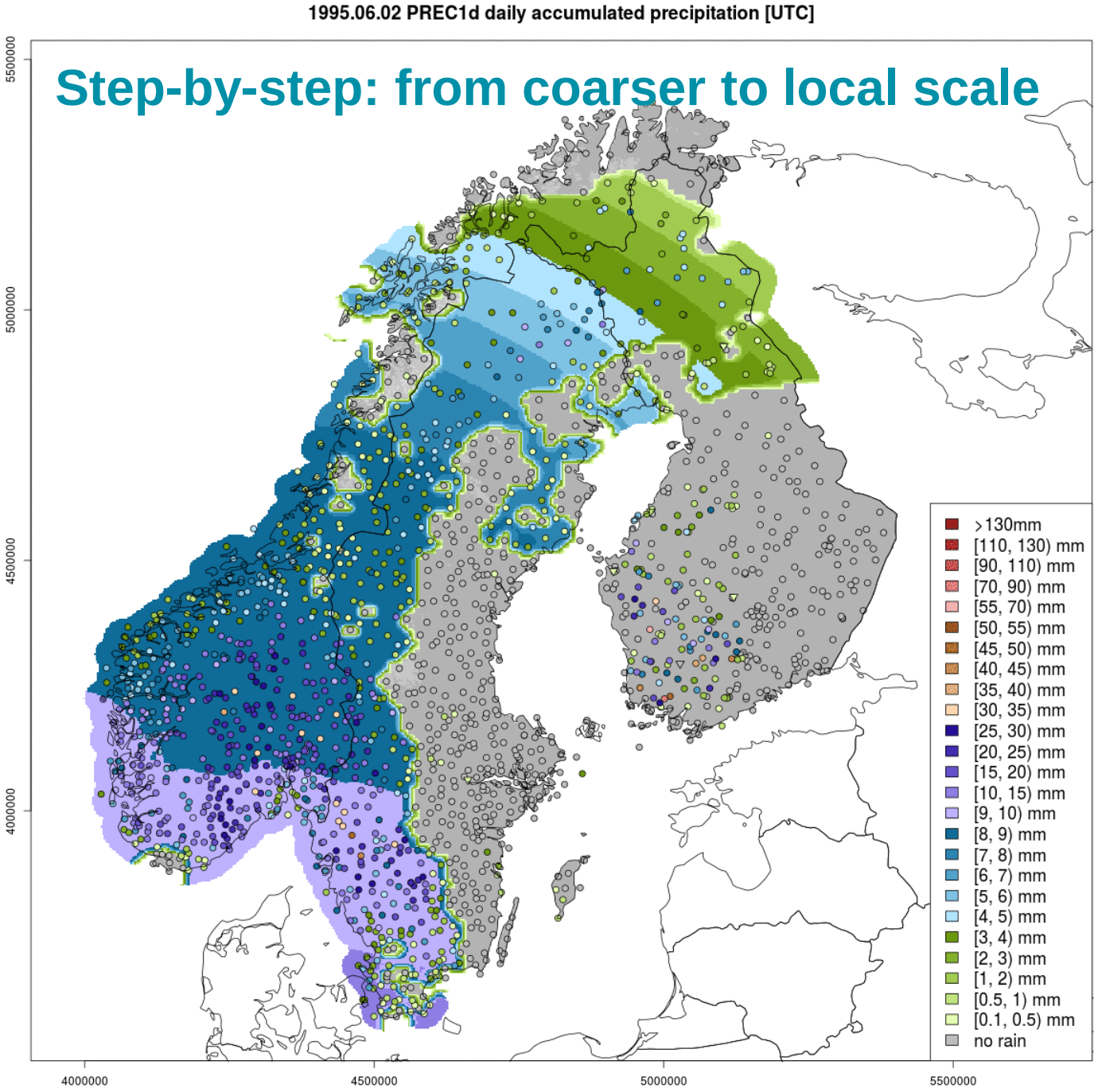
Given a predefined (horizontal) spatial *scale.*

OI assumptions:

- Additive error model:
  - $obs_{scale} = truth_{scale} + err_{scale}$
  - $back_{scale} = truth_{scale} + err_{scale}$
- Gaussian errors:
  - $err_{scale} = N(0, CovMat)$
- CovMat = f(*scale*,Vertical coord)
- OI (through leave-one-out cross validation) is used to optimize the influence of the vertical coordinate in the error covariance matrix

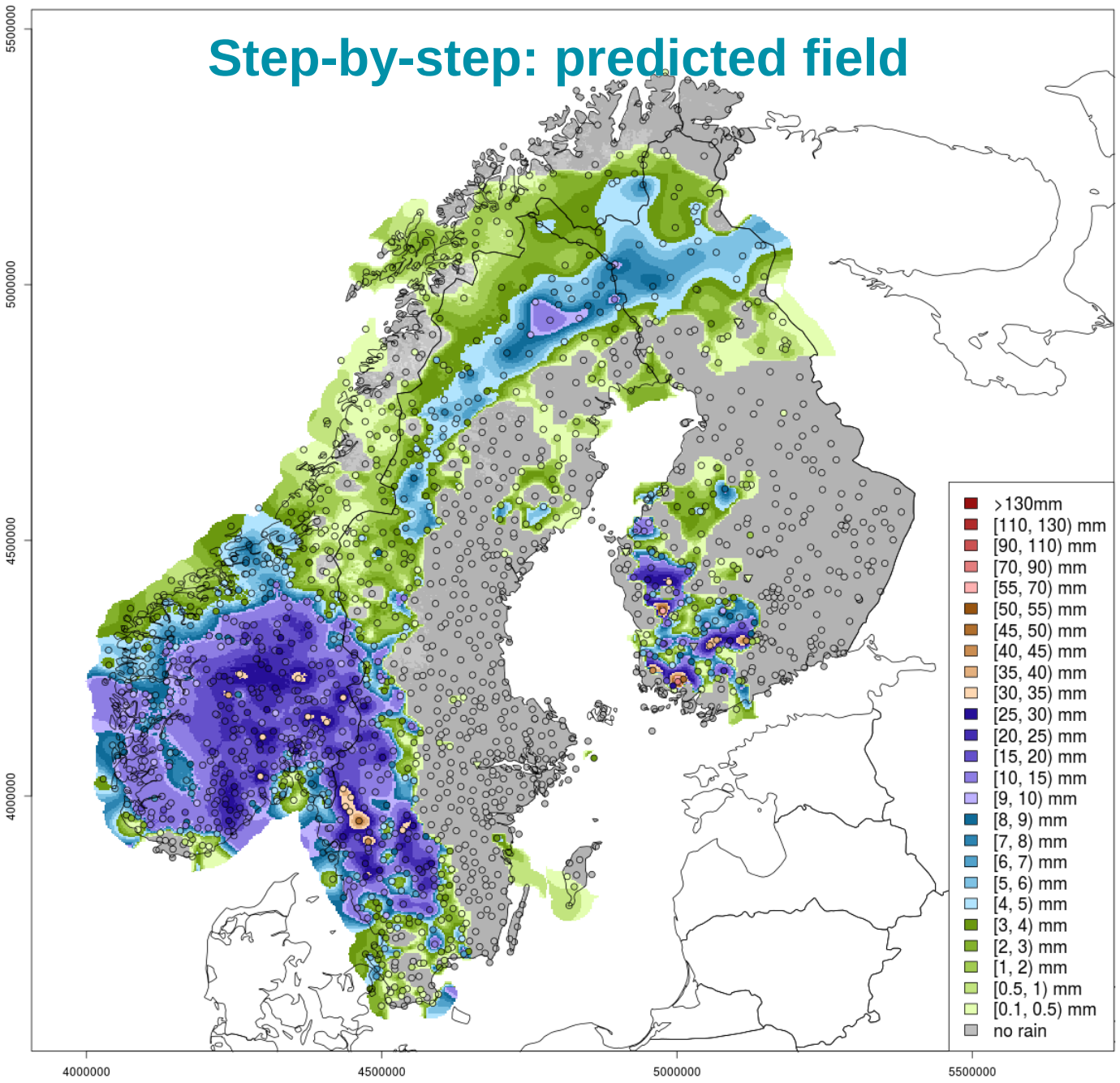
Multi-Scale Optimal Interpolation

Step-by-step: from coarser to local scale



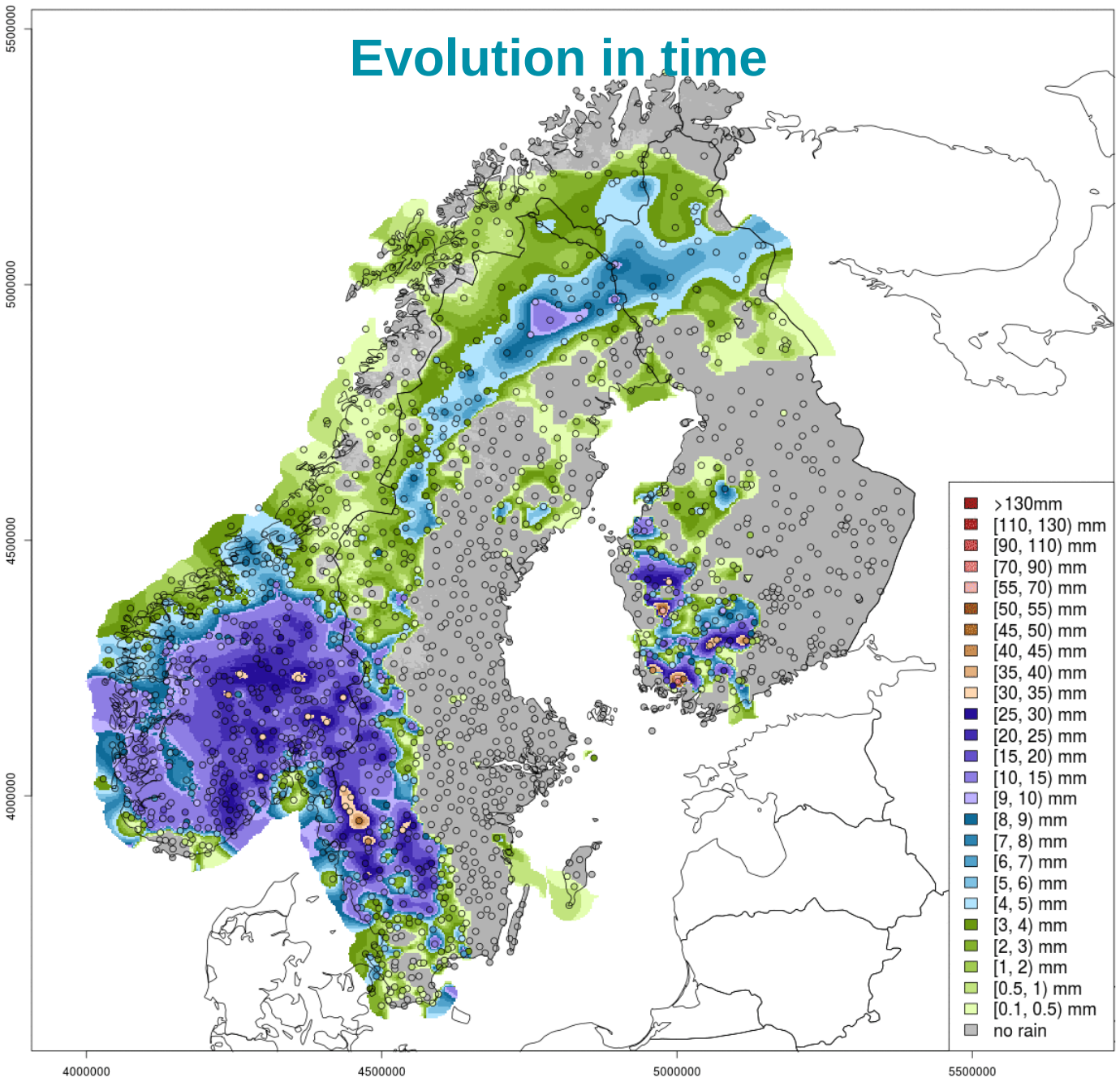
Multi-Scale Optimal Interpolation

Step-by-step: predicted field



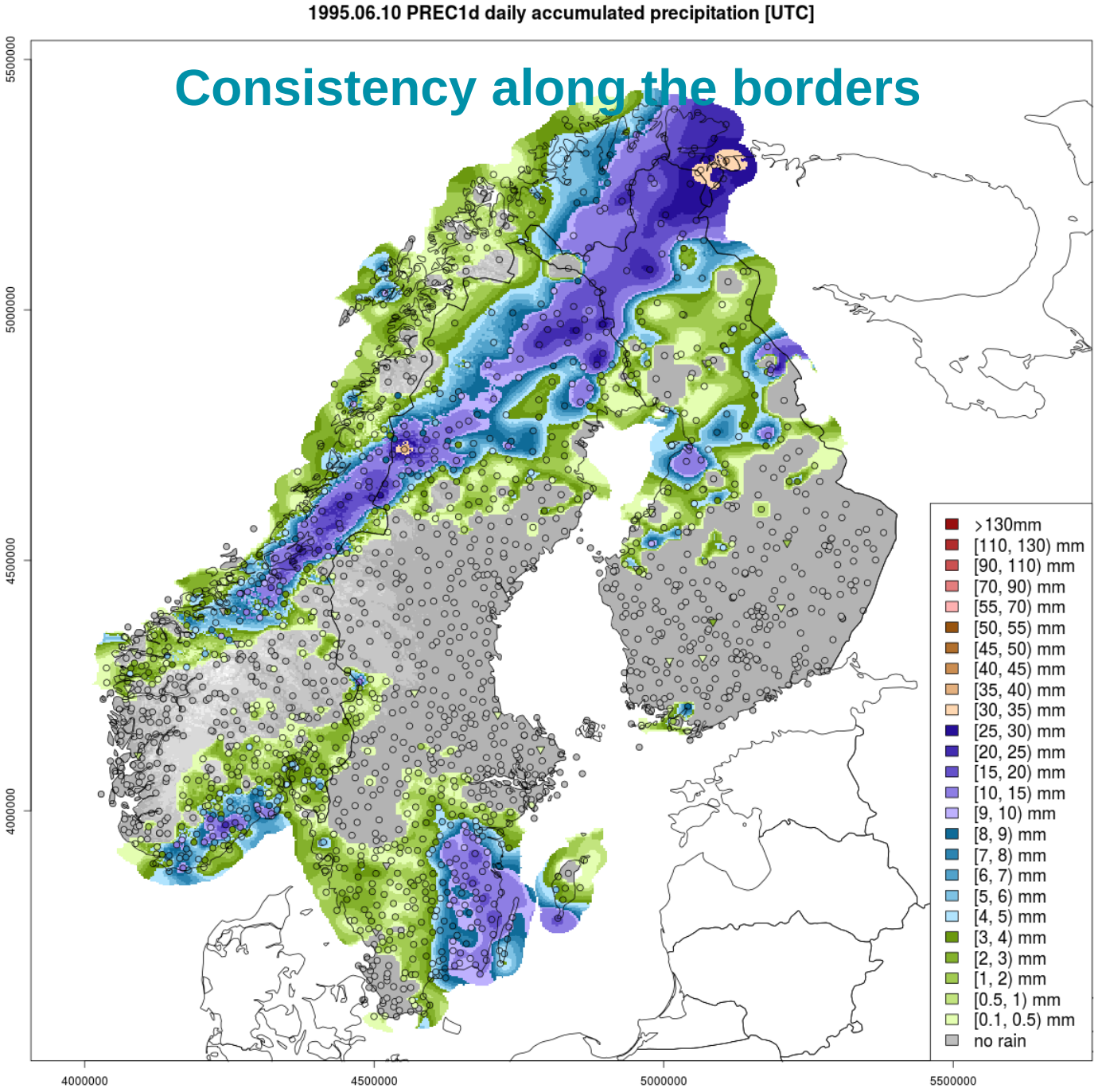
Multi-Scale Optimal Interpolation

Evolution in time

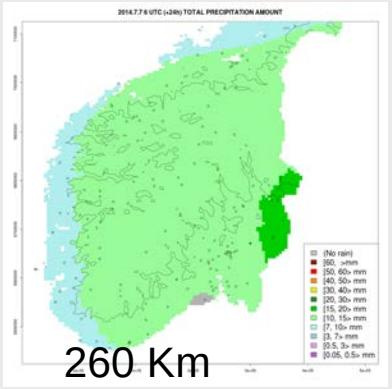


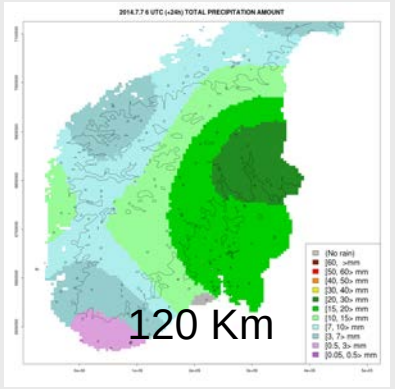
Multi-Scale Optimal Interpolation

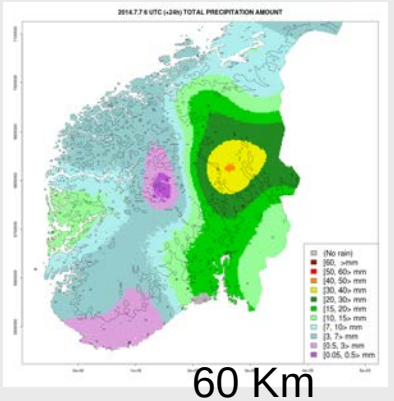
Consistency along the borders



Multiscale modified OI

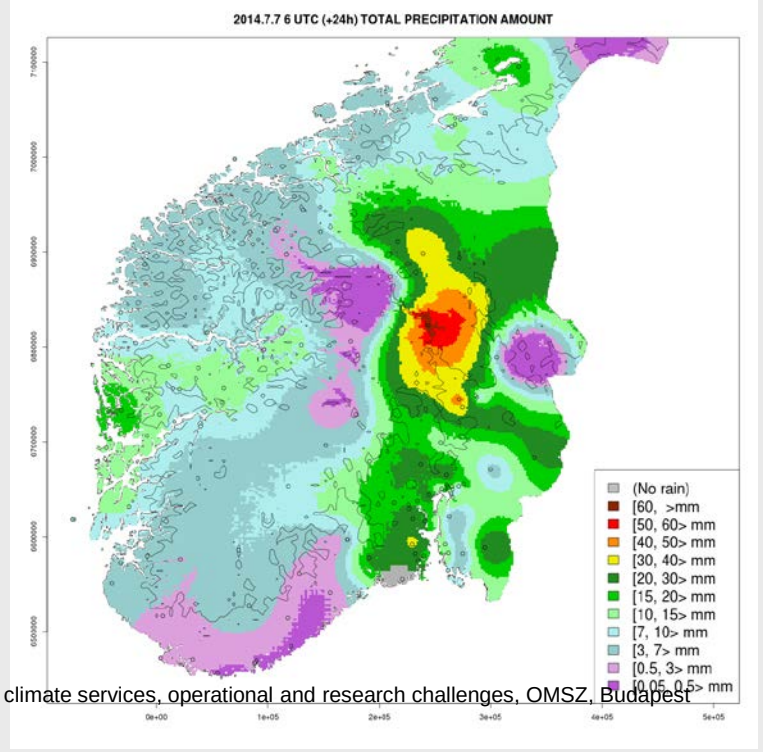






Step 1)
24h accumulation using 1h observed values

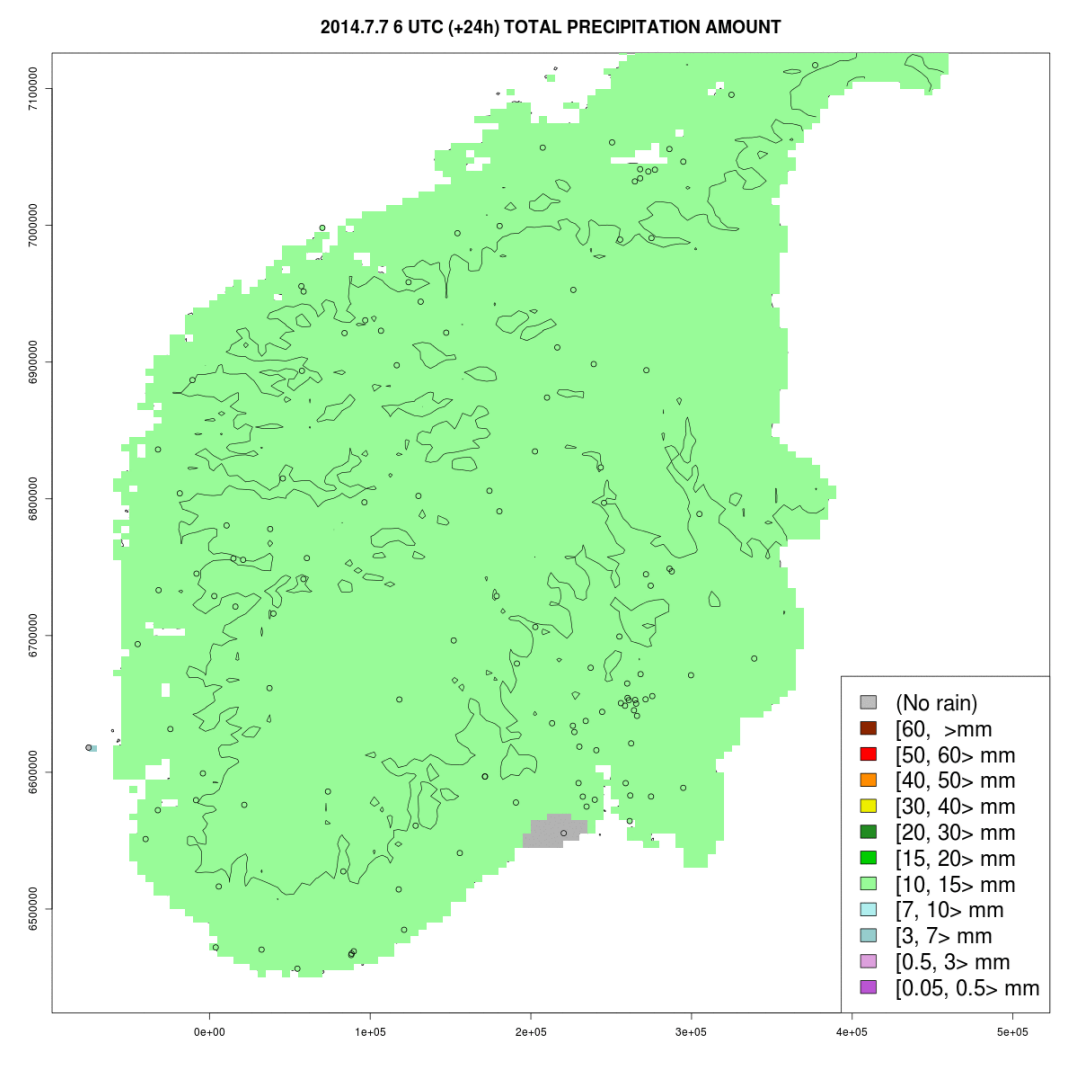
Step 2)
Spatial Interpolation



Final result

Norwegian Meteorological Institute

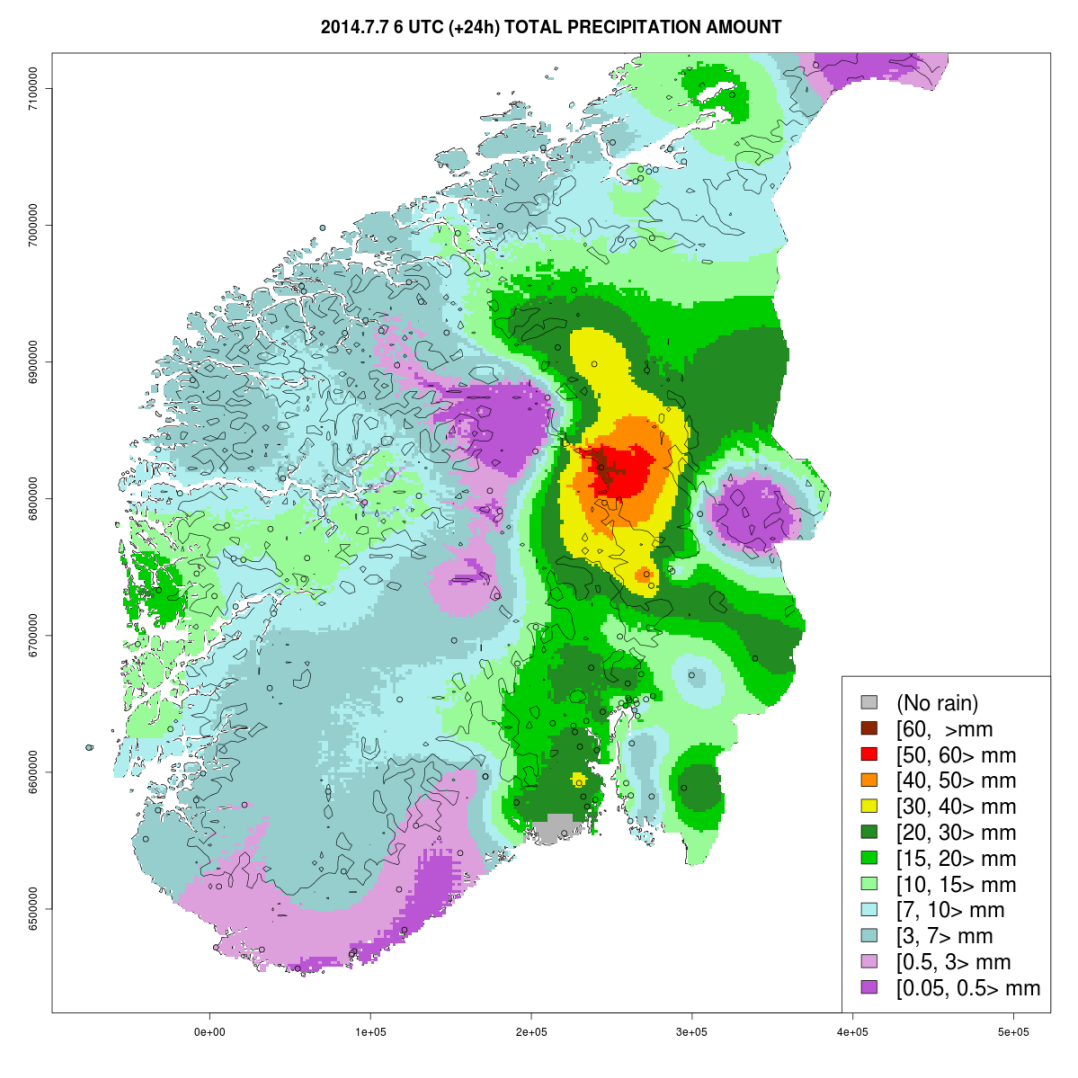
Multiscale modified OI



Norwegian Meteorological Institute

The importance of Station density

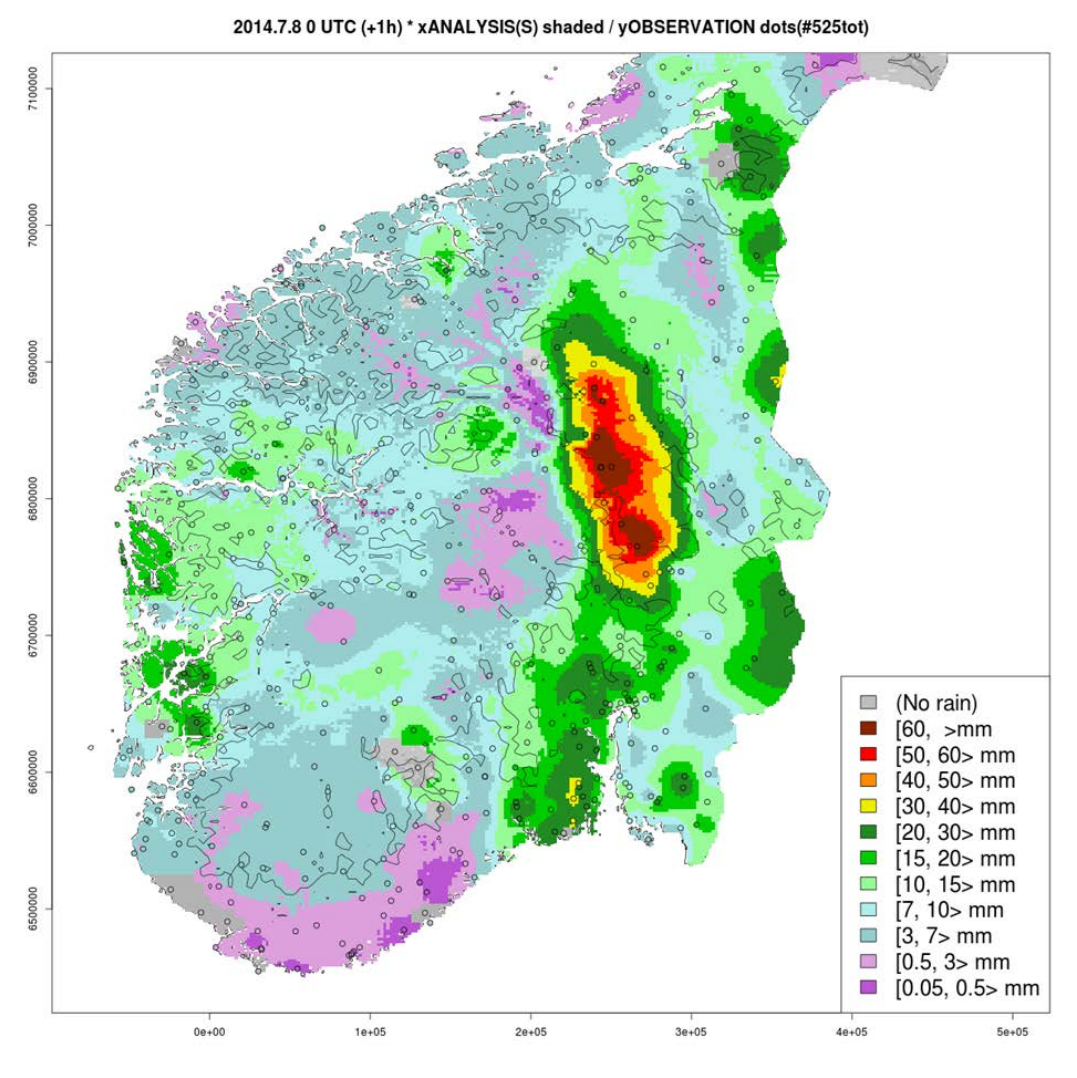
150 stations, 1h precipitation, (Figure shows 24h Prec)

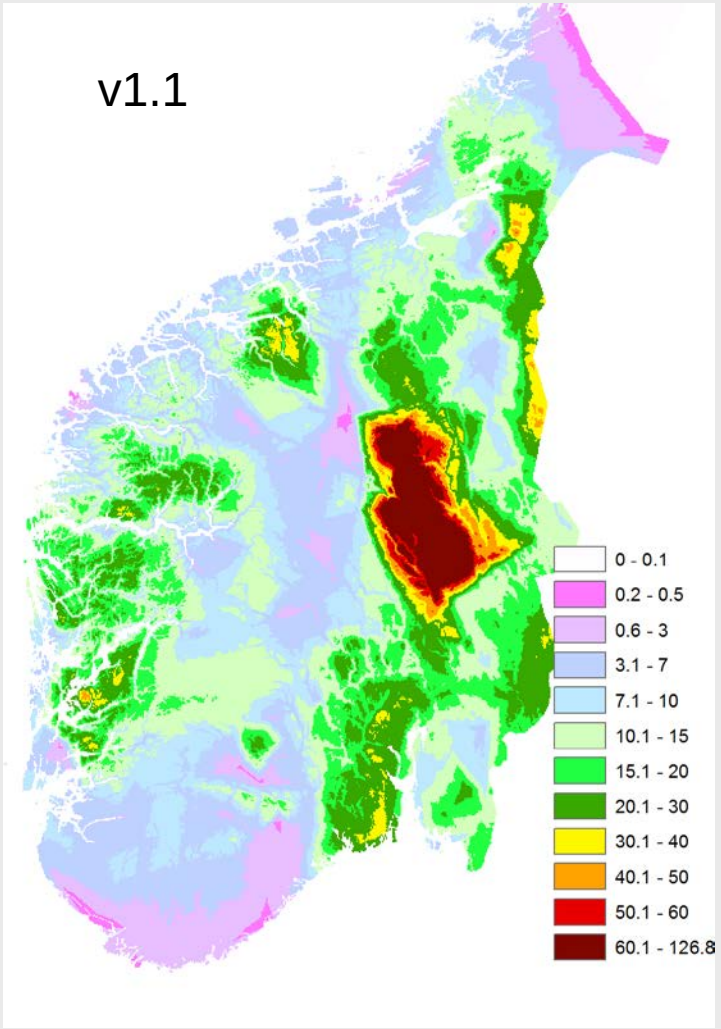


Norwegian Meteorological Institute

The importance of Station density

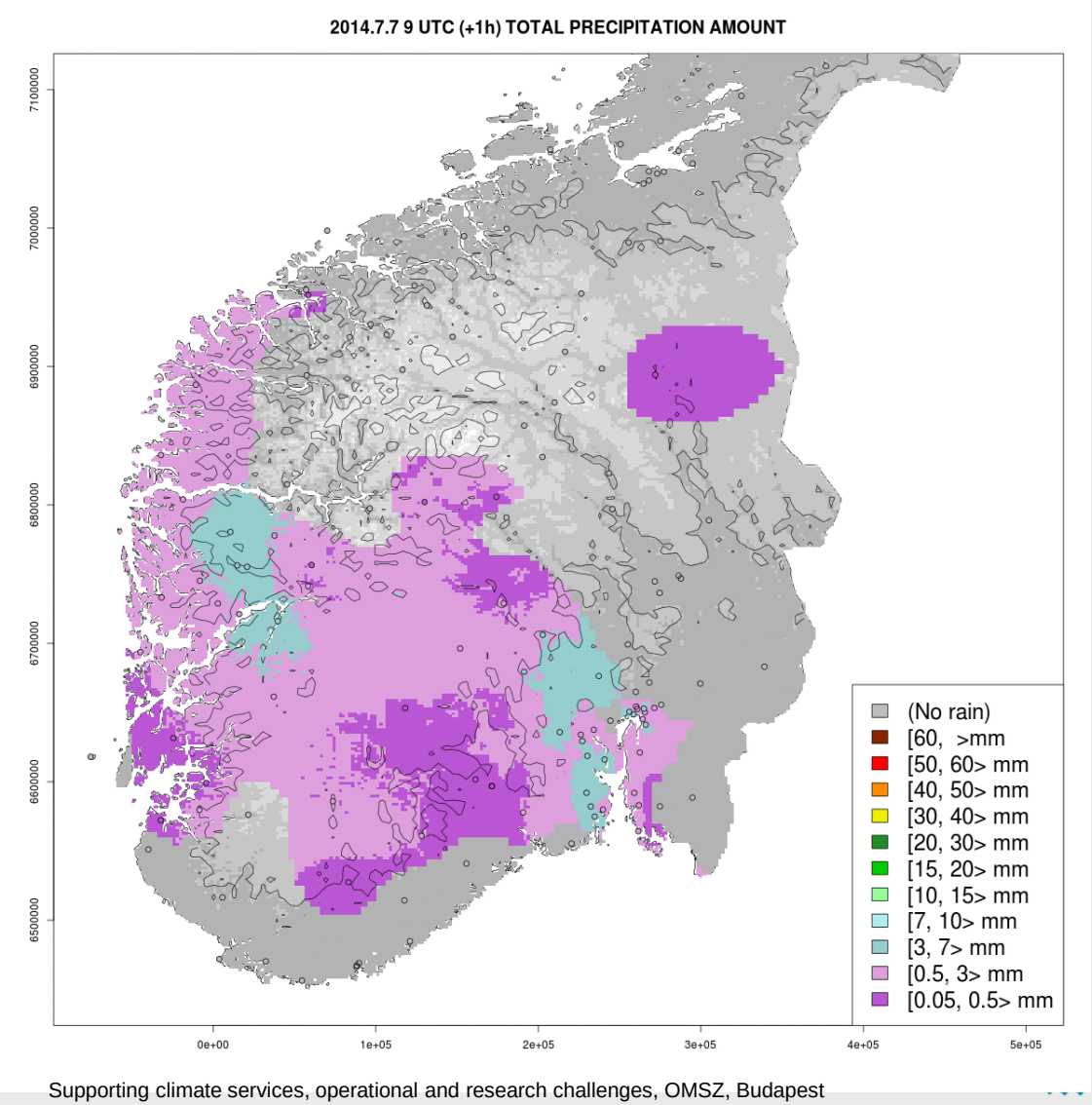
525 stations, daily precipitation





Norwegian Meteorological Institute

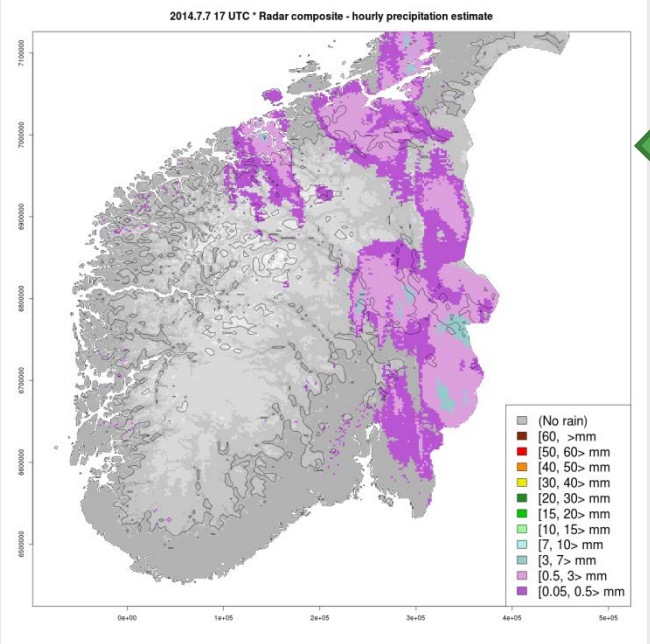
Hourly Maps



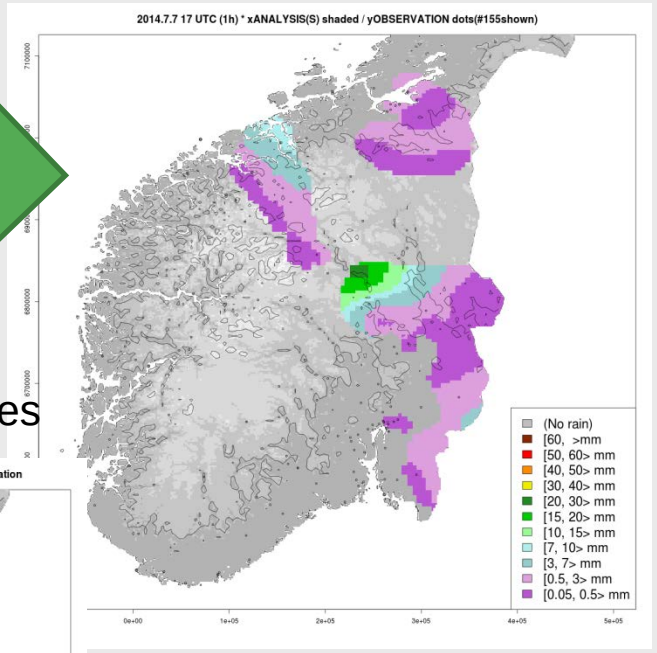
Norwegian Meteorological Institute

Convective rainstorm in Norway (7.July 2014)

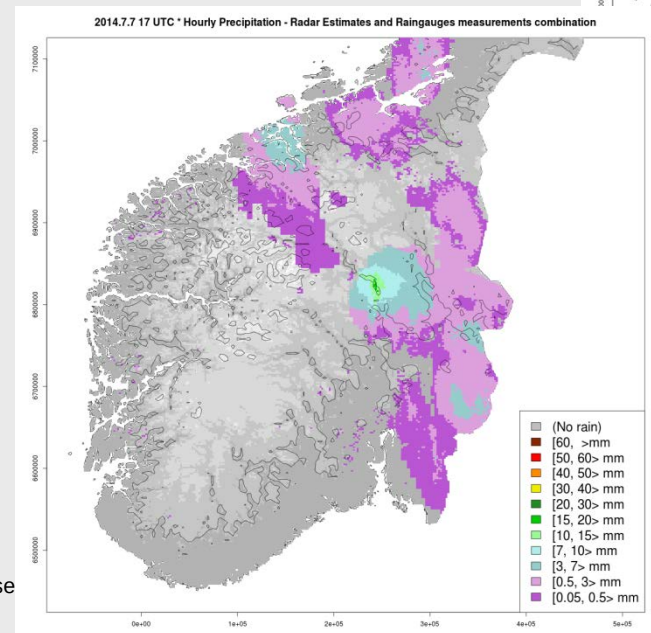
Radar



Automatic weather stations



Combination radar+raingauges



Gridding challenges

- Daily
- Hourly

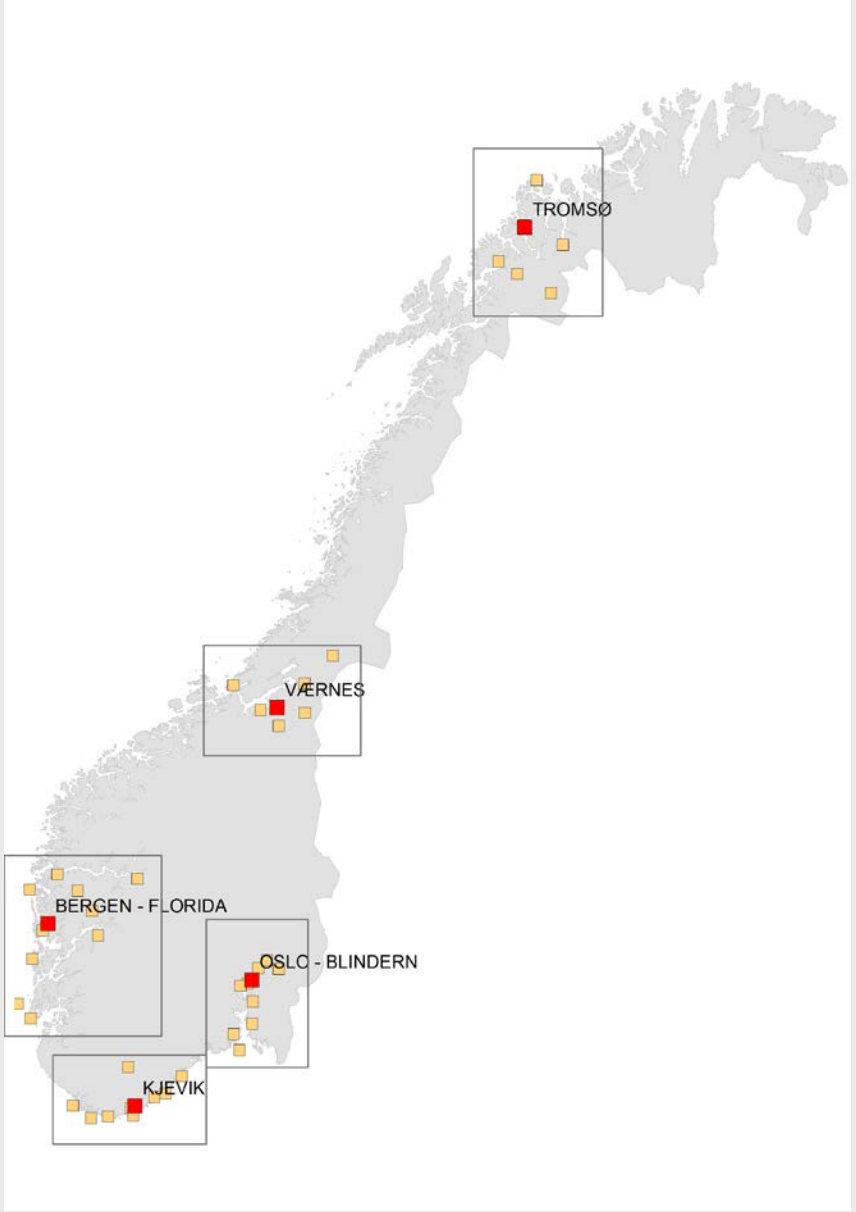
- Combine datasources
  - Observations
  - Radar
  - Model fields (NWP, RA)

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

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

Homogenization

- Daily homogenization of temperatures for five main cities
- Monthly precipitation for all Norway
- Daily precipitation for selected stations/key catchments.



Norwegian Meteorological Institute

Data management challenges

Establish consistent data management plans that include all types of climate data:

- In-situ observations
- Radar observations
- Satellite observations

- Gridded data
  - Observation grids
  - Reanalyses
  - NWP/Hindcast

Data management challenges

- Open data
- API
- User portals
  - User needs
  - Reproduction/modularity
- International standards
  - WMO Information System (WIS),
  - WMO Integrated Global Observing System (WIGOS)
  - Inspire
- Traceability
  - Versioning
  - Documentation

Partnerships

- **National**
  - Hydrology
  - Transportation (Road, Railway, Aviation authorities)
  - Agriculture
  - Municipalities
  - Universities
  - Research institutes
  - Large companies (with common interests)

Only relations that will support MET core activity

- **International**
  - **NORDIC**
    - Collaboration in operational NWP (SWE+NOR! DEN, FIN and Baltics to join?)
    - Climate services?
  - **European**
    - EU FP7 and H2020?
    - EUMETSAT
      - OSI-SAF
    - Copernicus
      - Have contracts in Marine services (operational)
      - ***C3S???***

Norwegian Meteorological Institute

Summary

- **Climate indicators** are strong and suitable climate measures for users in a wide range of sectors.
  - They contain condensed information of rather complex processes, making it more easily adaptable for the users.
  - They are well suited for adaptation studies.
  - They are easy to develop, according to user needs.
- **Gridded data** are a good basis for climate indicators
  - They are a supplement to the full description of the climate system.
  - Offers both a temporal and spatial dimension.
  - Consistent in time and space.

Summary - II

- The explosive increase in volume of climate data is challenge in management of climate data.
- Climate services (across national borders) will demand harmonisation and standards for climate data and climate services
- Collaborations and partnerships will be necessary
- User interaction and involvement is crucial

- Distributed services, big data, data sharing, open access…. Many challenges to face! We're just at the beginning!!

Norwegian
Meteorological
Institute