Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Meteorologisk institutt

Evaluation of reanalyses for precipitation in complex terrain: the Alps and the Fennoscandia

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29th November 2017

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(2) Norwegian Meteorological Institute, Oslo, Norway

SEVENTH FRAMEWORK PROGRAMME

UERRA
Uncertainties in Ensembles of Regional ReAnalyses

UERRA Evaluation

- Contributions of MeteoSwiss and Met Norway

  → Evaluate and quantify uncertainties of regional re-analyses using probabilistic forecast verification.

  → Precipitation (06h-06h)

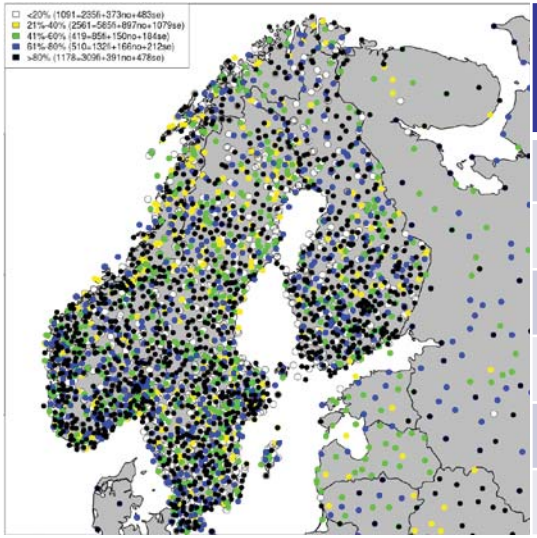
  → Alpine Region and Scandinavia

  → Scale dependency

	Dataset	Δx	Period	Information
GRIDDING	**APGD/APGDEns (REFERENCE)** **Alpine Precipitation Gridded Dataset**	**5 km**	**1971-2008**	**Alpine Region** **Isotta et al., 2014, Int. J. Climatol**
GRIDDING	**NGCD (REFERENCE)** **Nordic Gridded Climate dataset**	**1 km**	**1981-2010**	**Finland, Norway, Sweden (mainland)**
GRIDDING	E-Obs Gridded daily dataset	0.25° (~27 km)	1950-	Haylock et al. (2008) Klok and Klein Tank (2008)
REGIONAL REANALYSES	UK MetOffice Reanalysis ensemble	0.33° (~36 km)	2005-2010	20 members (→ mean and spread) Static 4DVAR
REGIONAL REANALYSES	UK MetOffice Reanalysis deterministic	0.11° (~12 km)	2005-2010	deterministic, uses ensemble reanalysis uncertainty in the assimilation
REGIONAL REANALYSES	HARMONIE reanalysis SHMI, Météo-France	11 km	1961-2015	deterministic **2 different physics (2006-2010)**
REGIONAL REANALYSES	COSMO-REA6 University of Bonn	0.055° (~6 km)	1997-2014	deterministic COSMO + nudging
REGIONAL REANALYSES	COSMO-EU reanalysis University of Bonn	12 km	(2006-2010)	21 members, ensemble-nudging data assimilation (probabilistic observations)
REGIONAL REANALYSES	NORA10 Norwegian Reanalysis 10 km	0.1° (~10 km)	1958-2016	deterministic Norway
DOWN SCALING	MESCAN Météo-France	5.5 km	1961-2010	MESCAN-SURFEX-TRIP-HR Model: HARMONIE 11 km **6-8 members (different physics) 2006-2010**
DOWN SCALING	MESAN (EURO4M) HIRLAM model, downscaling	5.5 km	1989-2010	Häggmark et al. 2000, Daley, 1991 (optimal interpol). Mesoscale analysis system, SHMI
GLOBAL REANAL.	ERA-INTERIM	80 km	1979-	ECMWF, Dee et al. (2011)
GLOBAL REANAL.	ERA20C	125 km	1900-2010	ECMWF

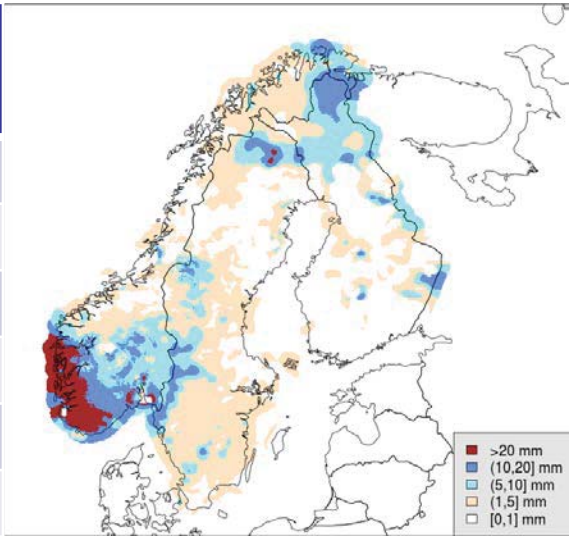
+ E-Obs Ens, ERA-5

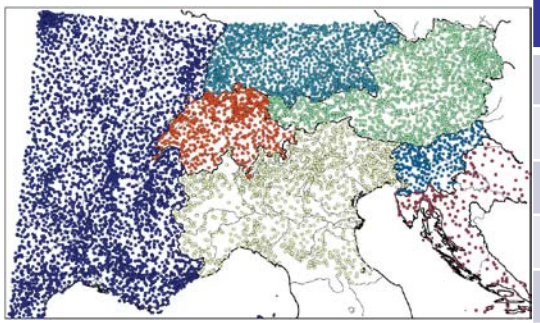
Reference Datasets



Nordic Gridded Climate dataset (NGCD)

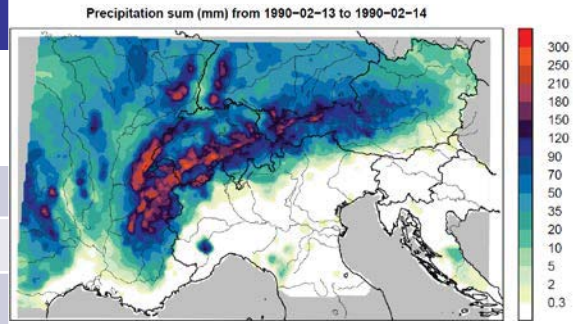
Variable	Precipitation
Δx	1km
t	1981-2010, daily
x	Finland, Norway, Sweden (mainland)
Stations	~3850
Source	ECA&D, eklima.met.no, SMHI + FMI





Alpine Precipitation Grid Dataset (APGD)

Variable	Precipitation
Δx	5km
t	1971-2008, daily
x	Alpine Region (2-17.5E, 43-49N)
Stations	>8500 (~6000 per day)
Quality	Quality checked



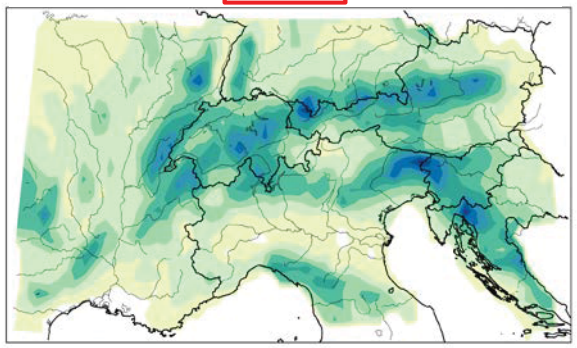
→ **Rescaling to 25km and 5km grid**

Mean annual precipitation

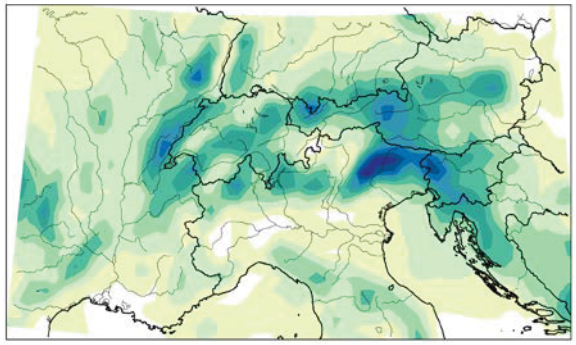
Norwegian Meteorological Institute

2005-2008
25 km grid
Gridding
Regional Rean.
Downscaling
Global Rean.

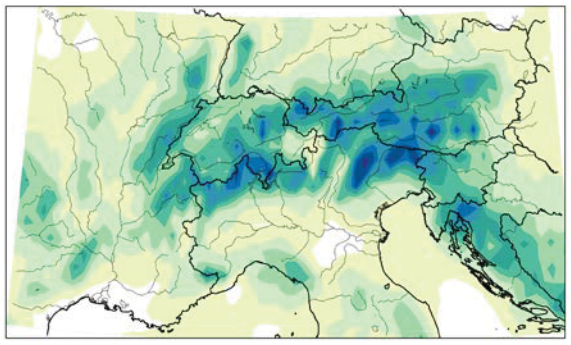
APGD



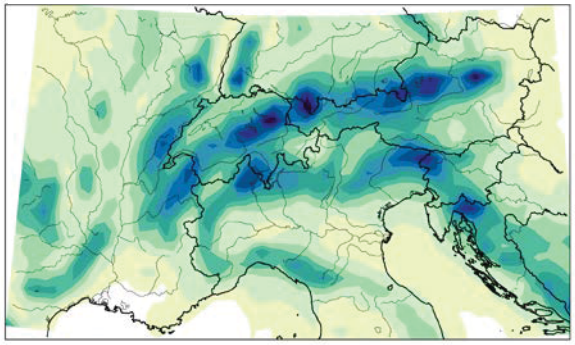
MESAN (EURO4M)



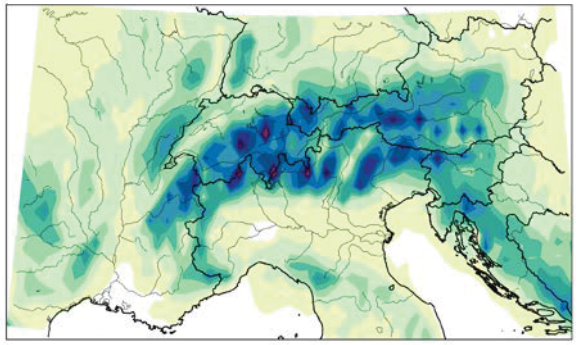
MESCAN



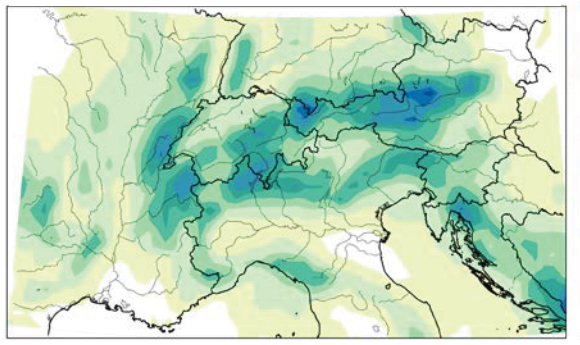
UKMO det

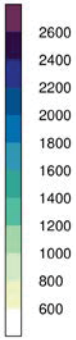


HARMONIE v1

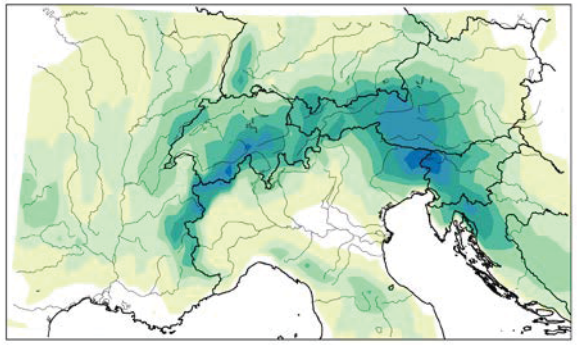


COSMO6-REA





E-Obs



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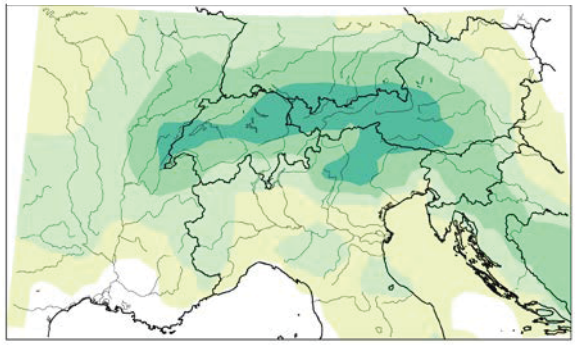
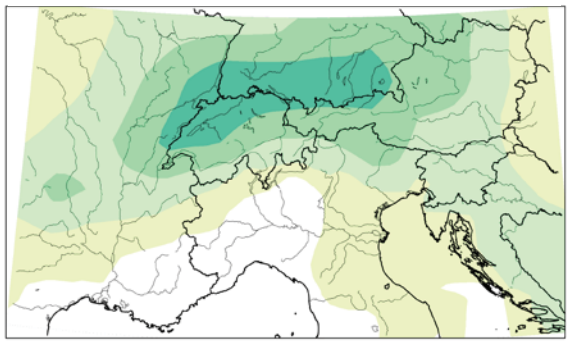


ERA20C

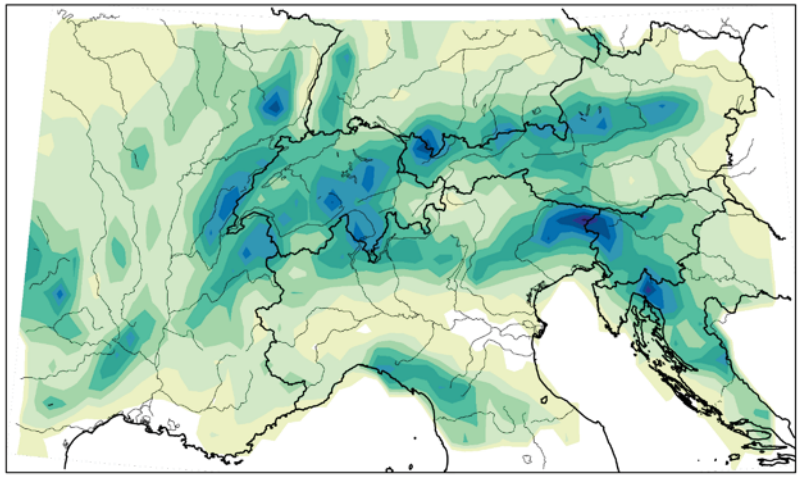


Mean annual precipitation

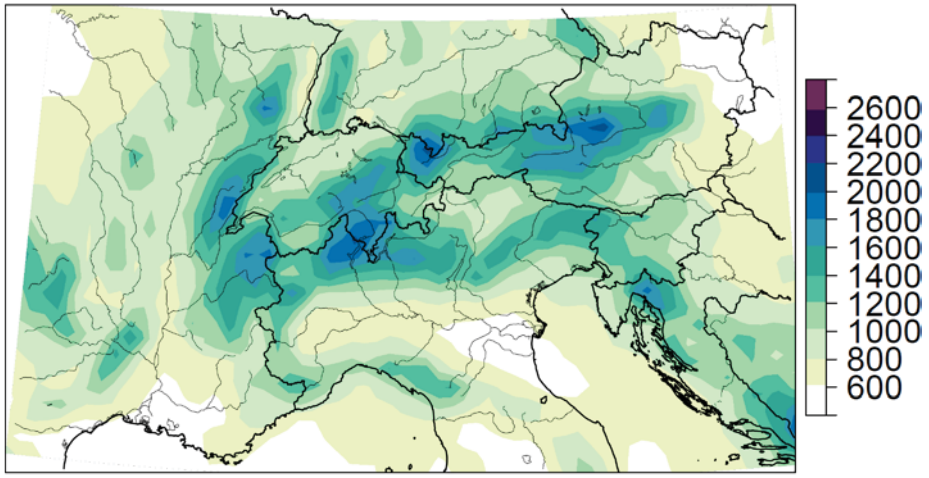
2006-2008
25 km grid

Norwegian Meteorological Institute

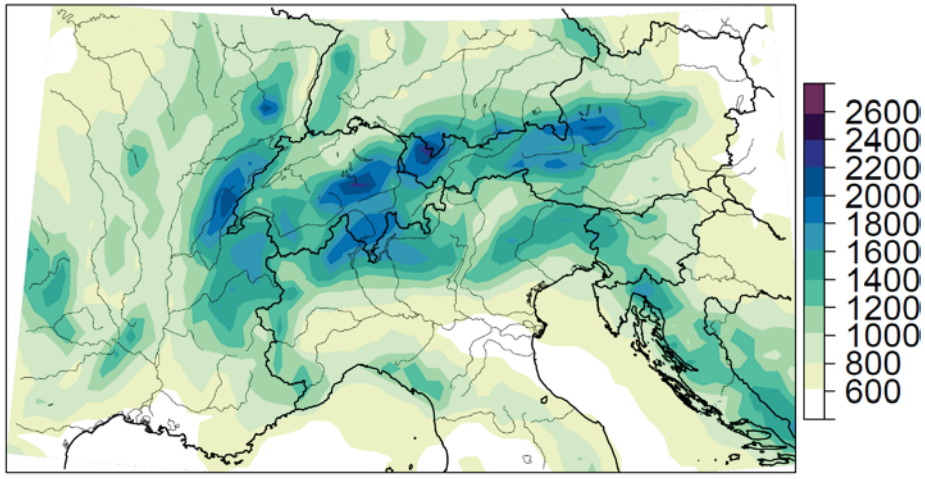
APGD



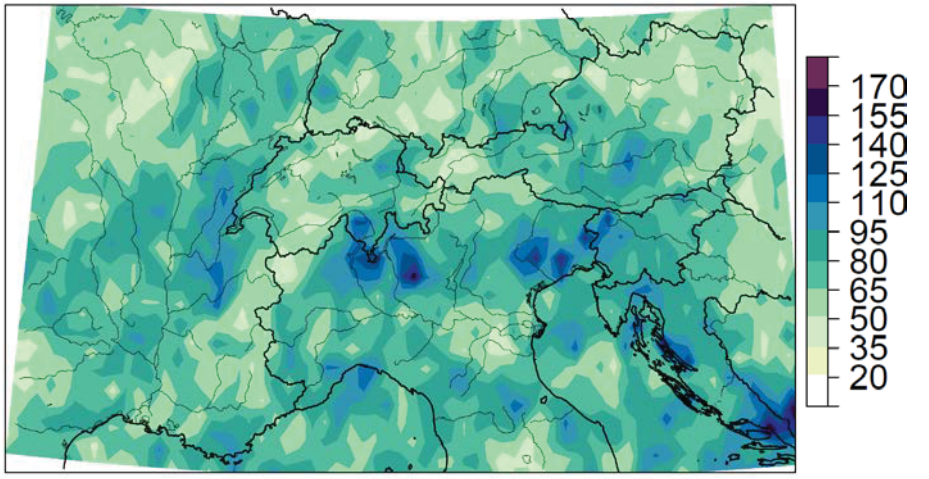
COSMO6-REA



COSMO-ENS ensemble median



COSMO-ENS interquant. (90%-10%)

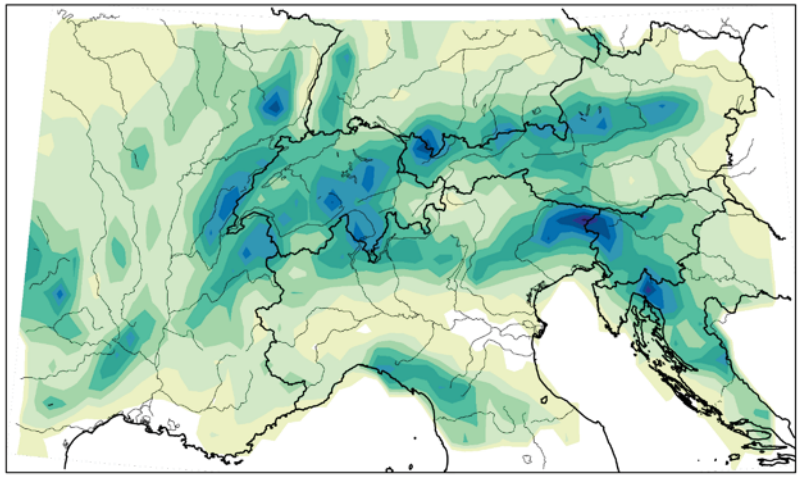


Mean annual precipitation

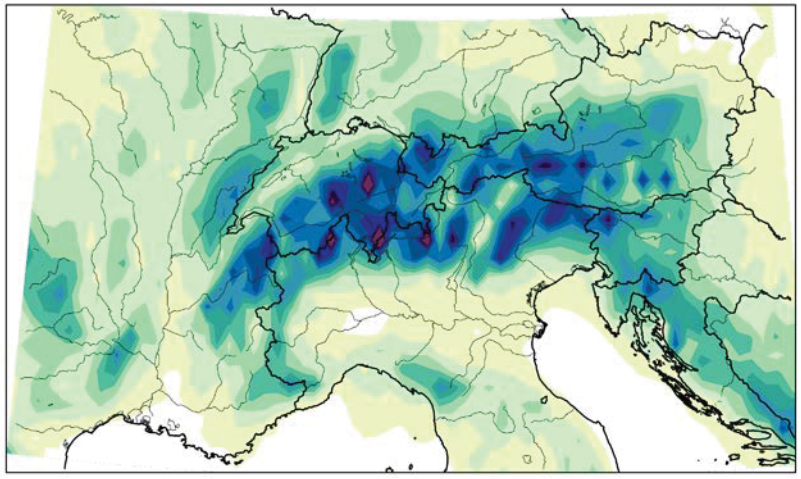
2006-2008
25 km grid

Norwegian Meteorological Institute

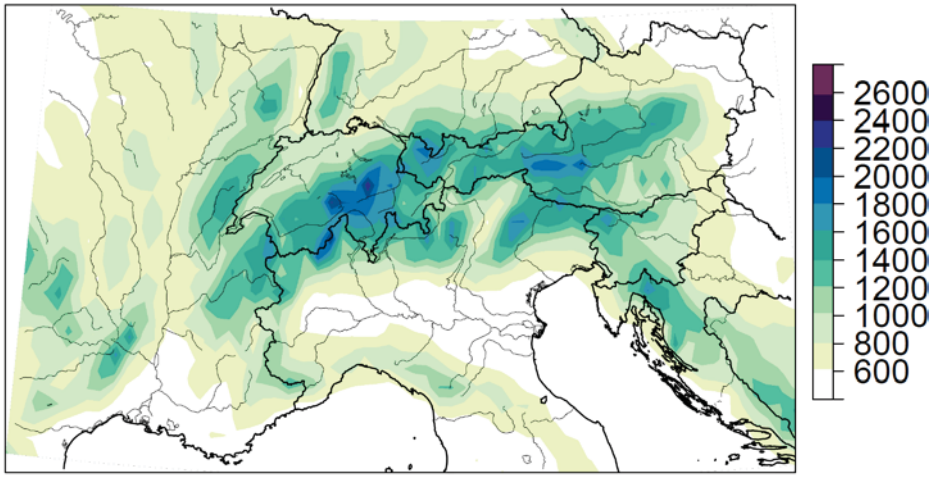
APGD



HARMONIE v1



HARMONIE v2

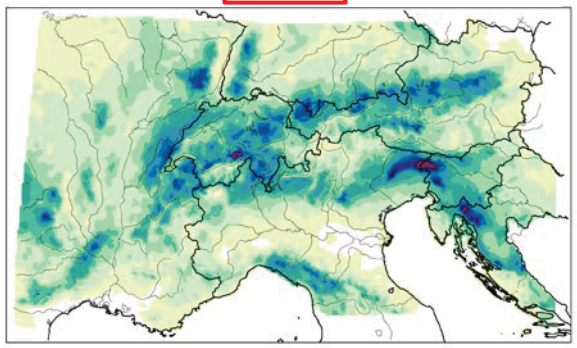


Mean annual precipitation

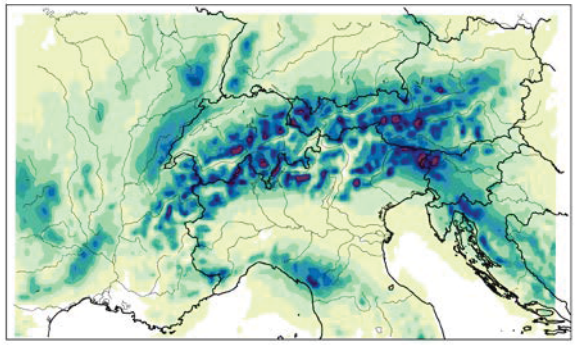
2006-2008
5 km grid

Norwegian Meteorological Institute

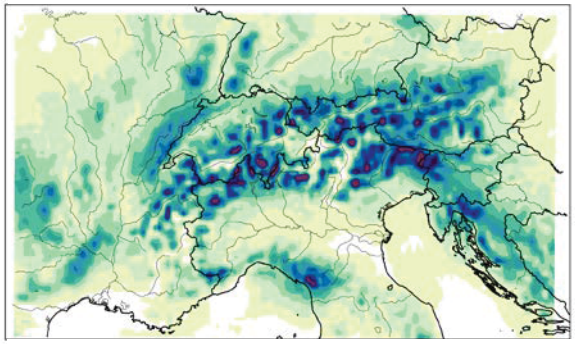
APGD



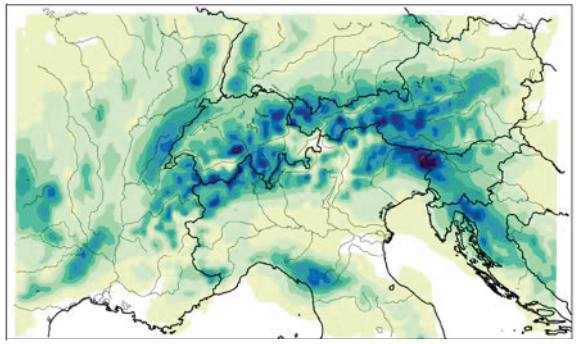
HARMONIE v1 (rescaling 5km)



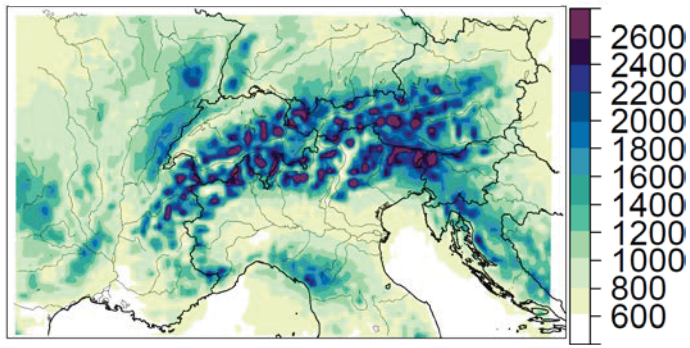
MESCAN Bkg:DS/AD,obs:HD



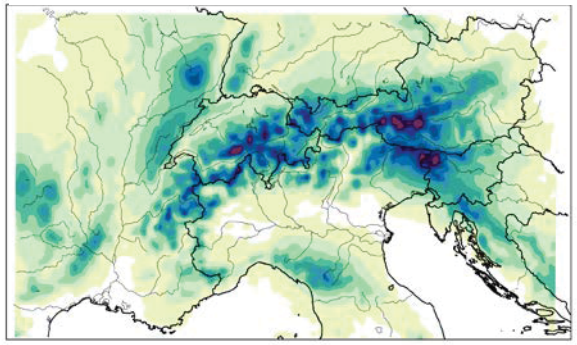
MESCAN Bkg:DS/AR,obs:HD



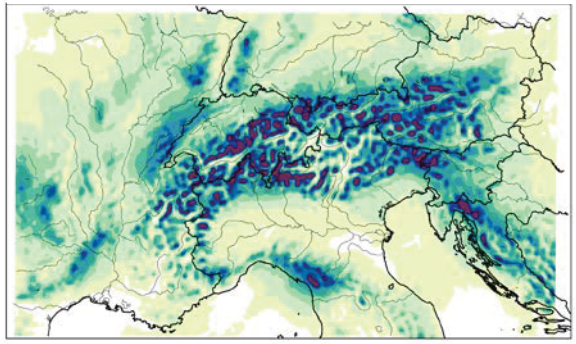
MESCAN Bkg:DS/AD,obs:LD



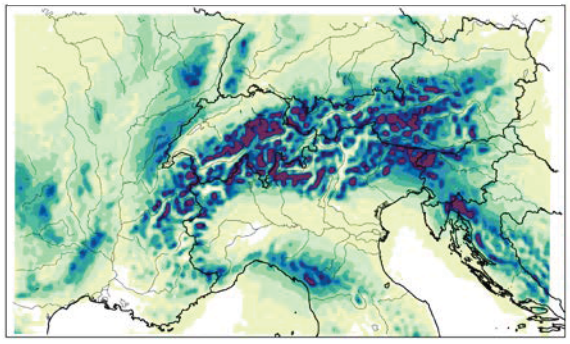
MESCAN Bkg:DS/AR,obs:LD



MESCAN Bkg:AD,obs:HD



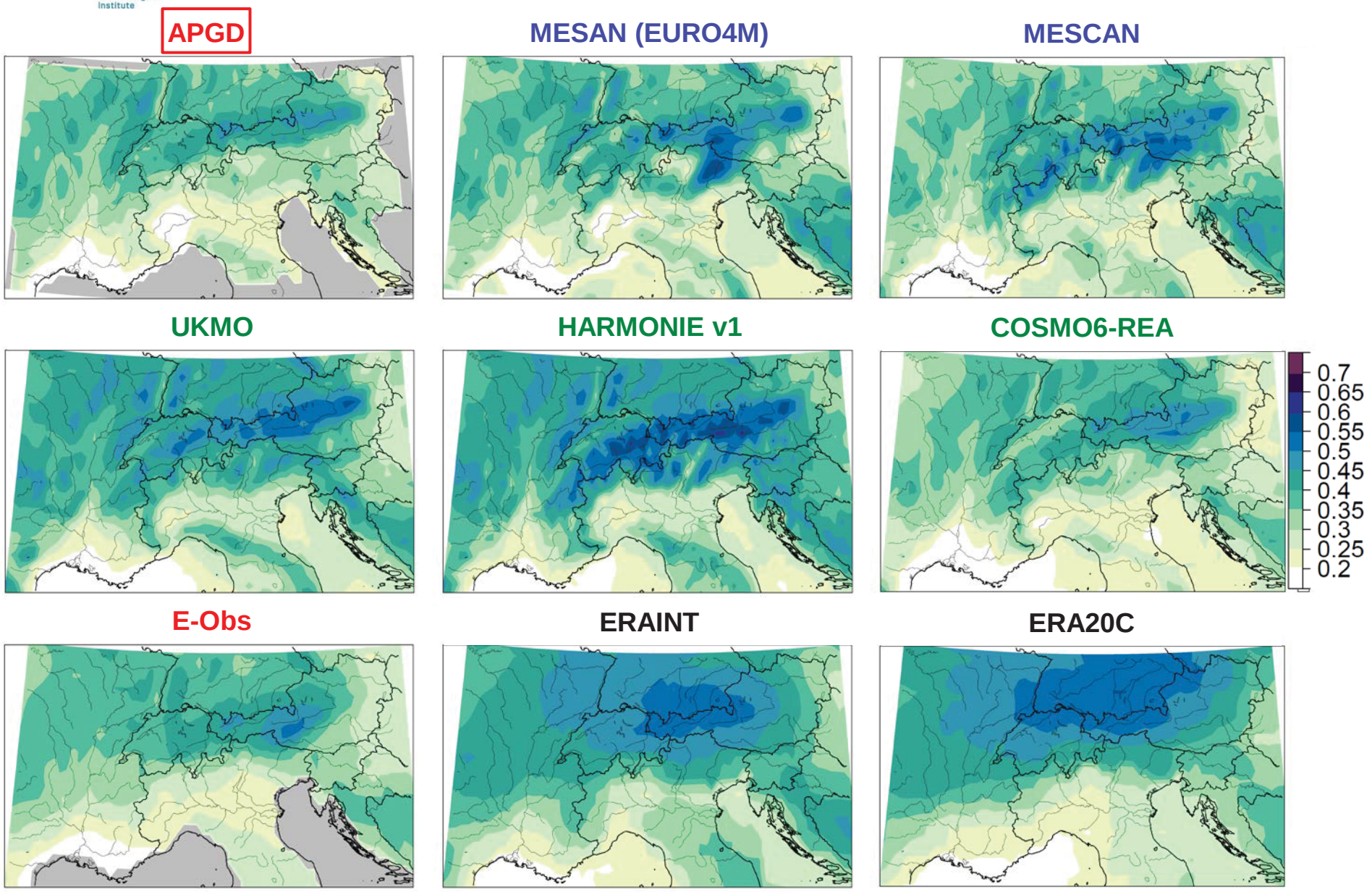
MESCAN Bkg:AD,obs:LD



Wet-days frequency ≥ 1mm/d

2005-2008
25 km grid

Norwegian Meteorological Institute

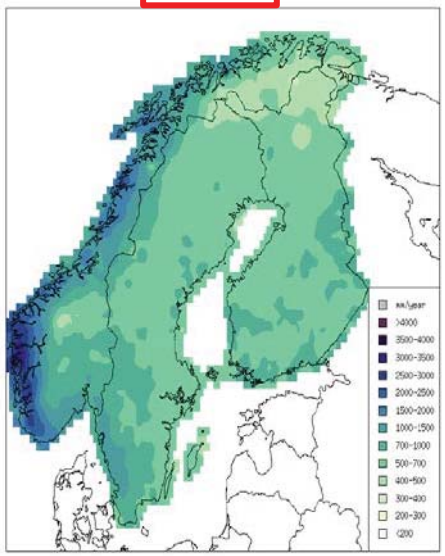


Norwegian Meteorological Institute

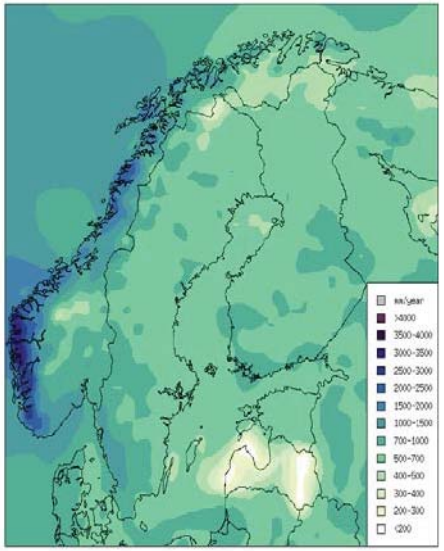
Mean annual precipitation

2005-2008
25 km grid
Gridding
Regional Rean.
Downscaling
Global Rean.

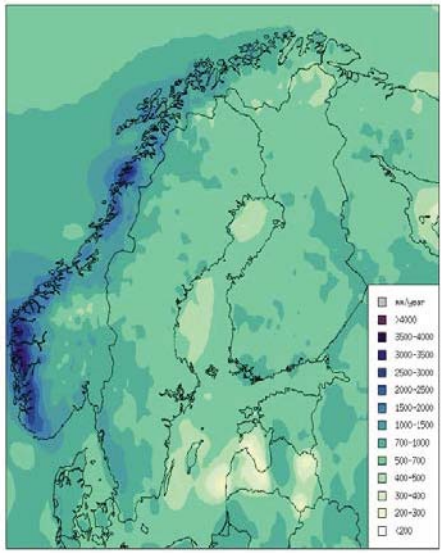
NGCD



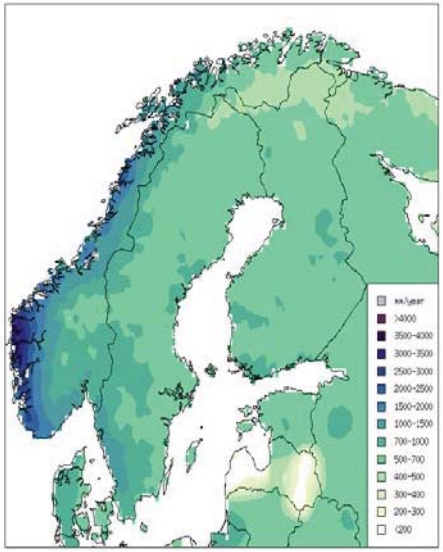
MESAN



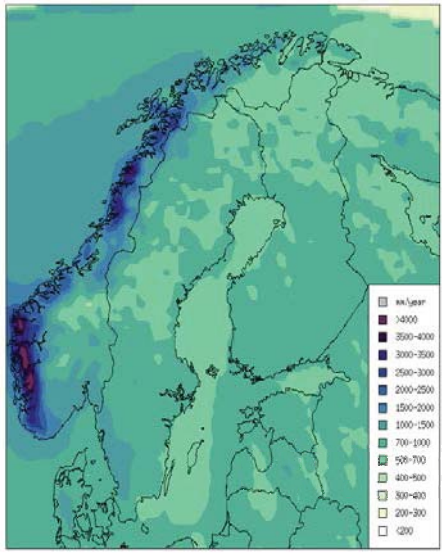
MESCAN



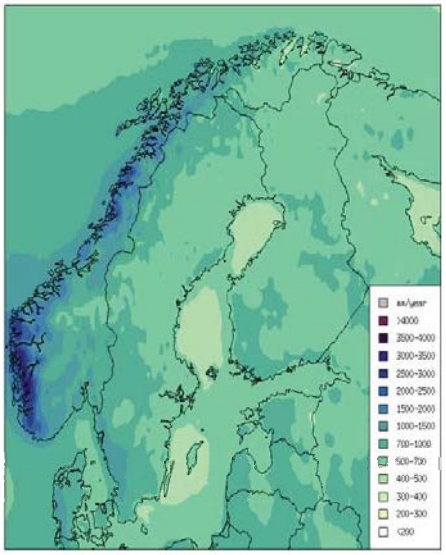
EOBS



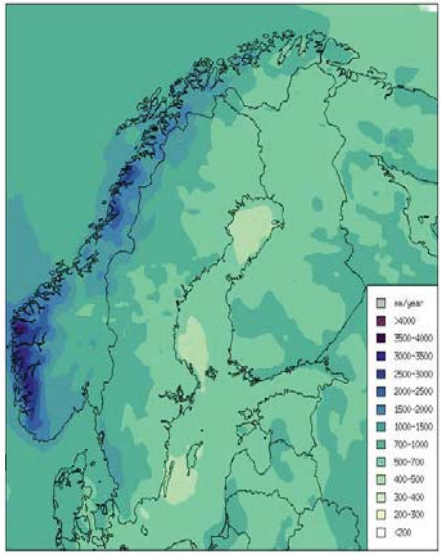
UKMO det



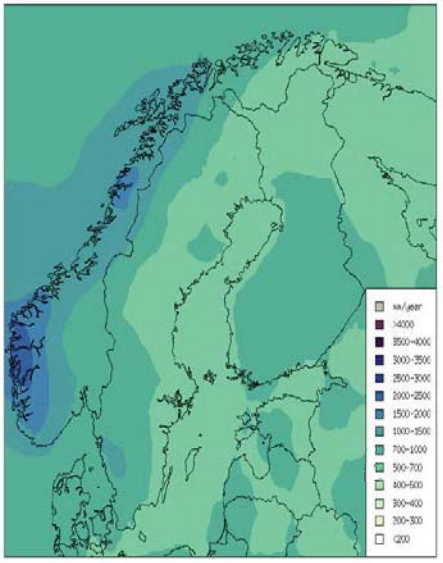
HARMONIE v1



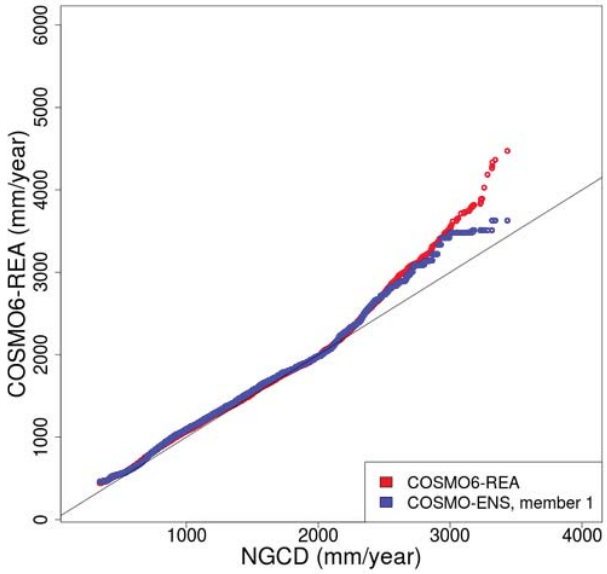
COSMO6-REA

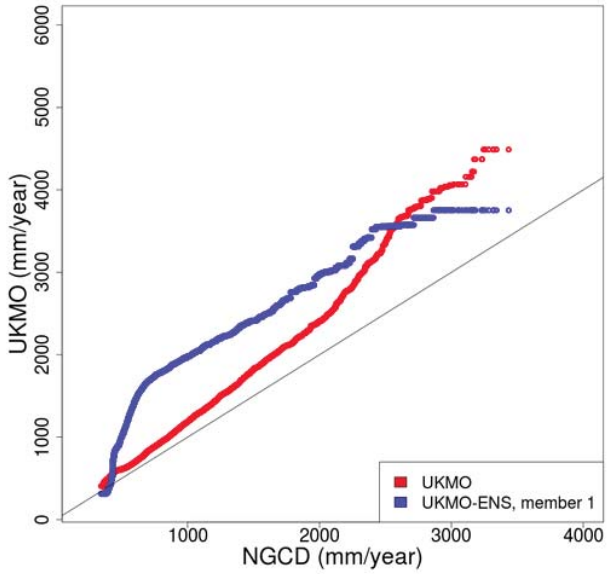


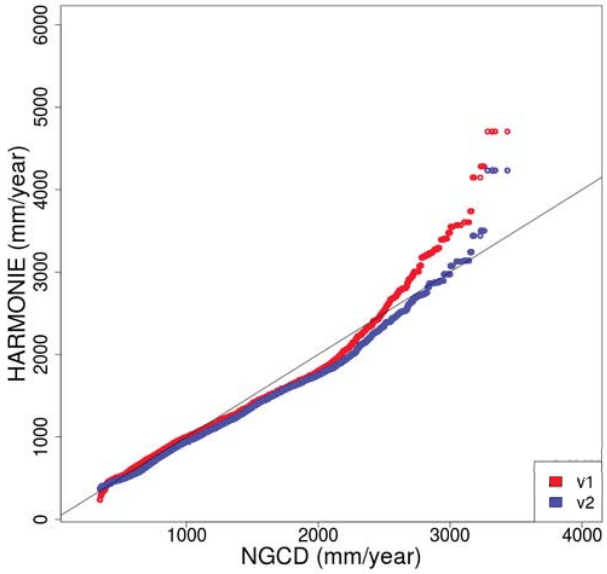
ERAINT

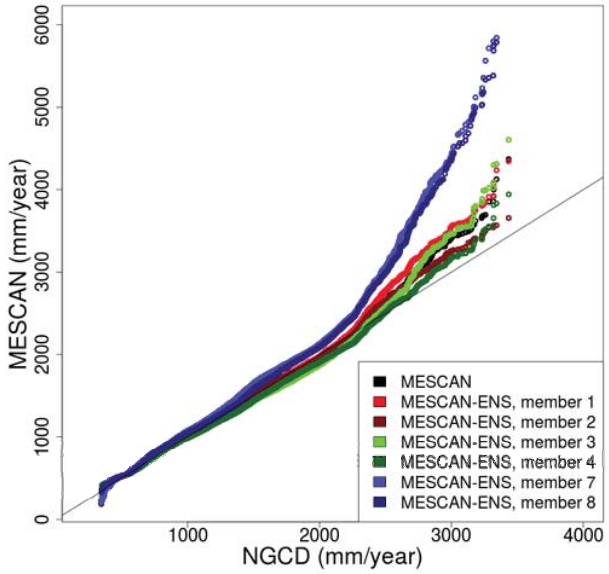


Mean annual precipitation









Quantile-quantile plot for the mean annual precipitation.

The reference (x-axis) is NGCD.

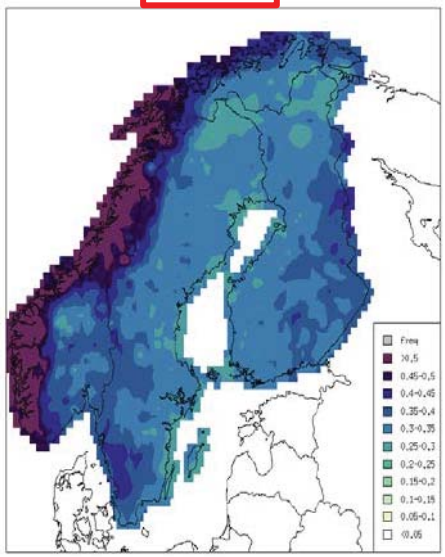
Only UERRA datasets are shown.

Norwegian Meteorological Institute

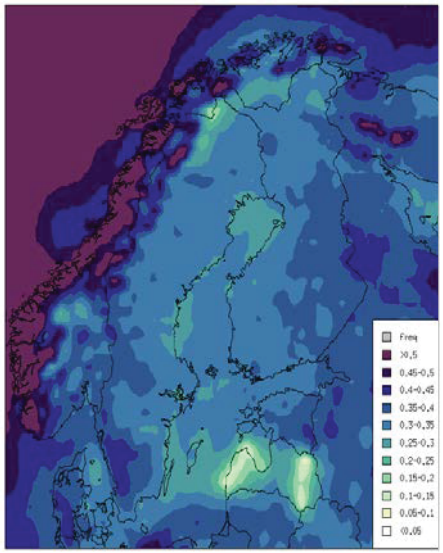
Wet-days frequency ≥ 1mm/d

2005-2008
25 km grid
Gridding
Regional Rean.
Downscaling
Global Rean.

NGCD



MESAN



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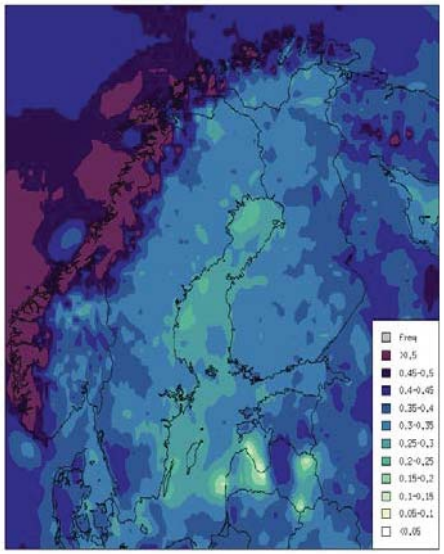
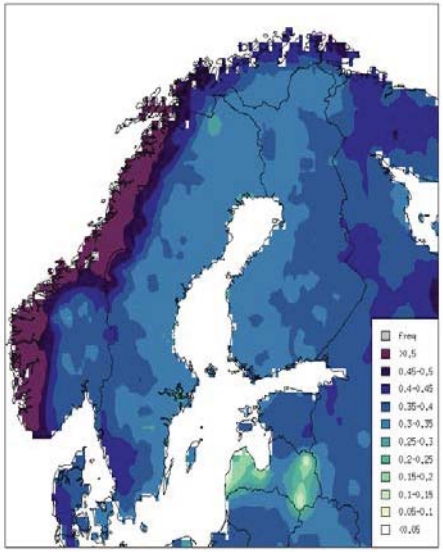


EOBS



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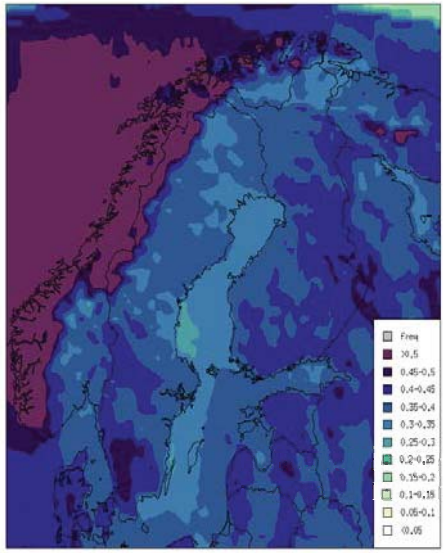
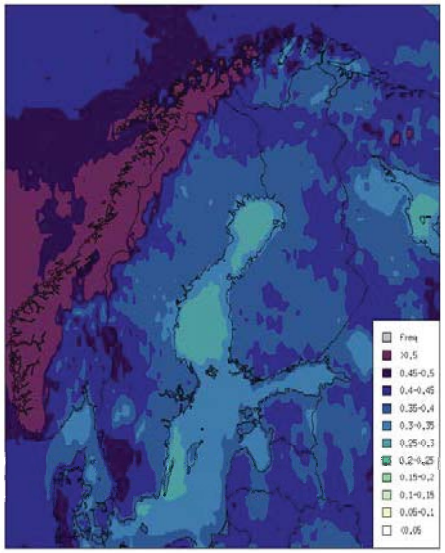
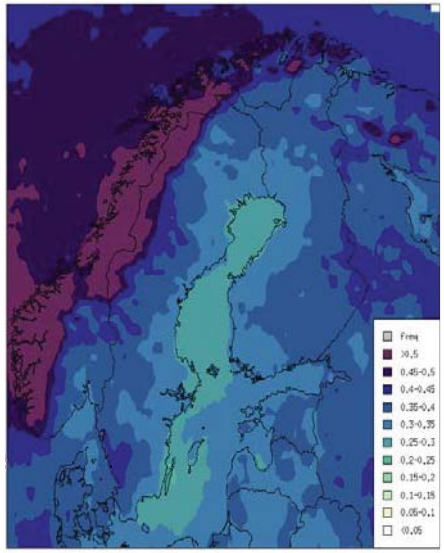


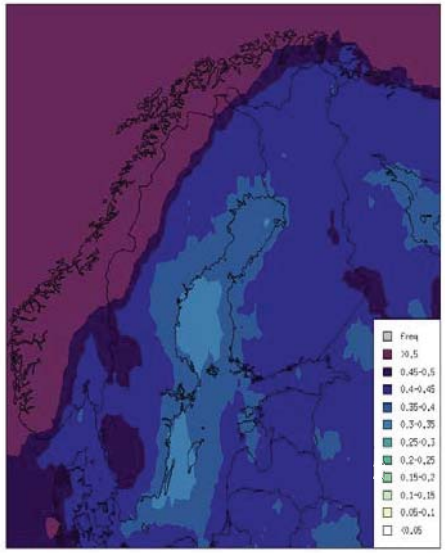
HARMONIE v1



COSMO6-REA



ERAINT

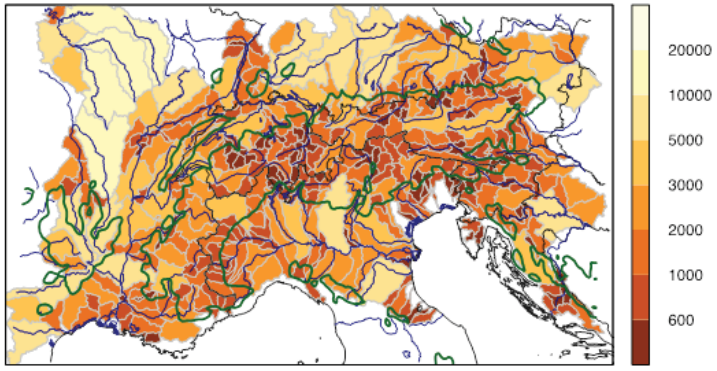


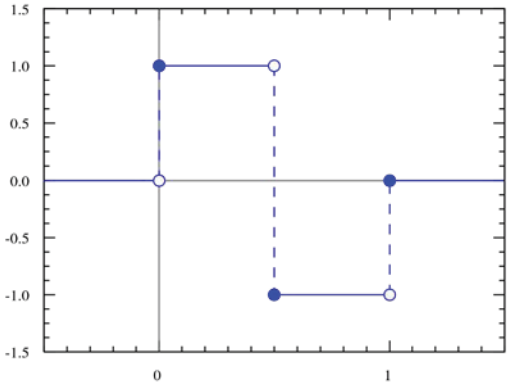
Scale dependency

→ Skill of models, uncertainty depend on scale

→ Scale dependent evaluation

Two methods





«Polygoning»

Scale separation on catchment areas of different size classes

«Wavelet»

Mathematical-theoretical scale separation

Verification method: Wavelet

Scale decomposition approach based on the Haar wavelet filter

Key points:

1. Decompose reanalysis and observation fields into the sum of spatial components on different scales (wavelets)
2. Perform verification on different scale components, separately

Account for the field coherent spatial structure:

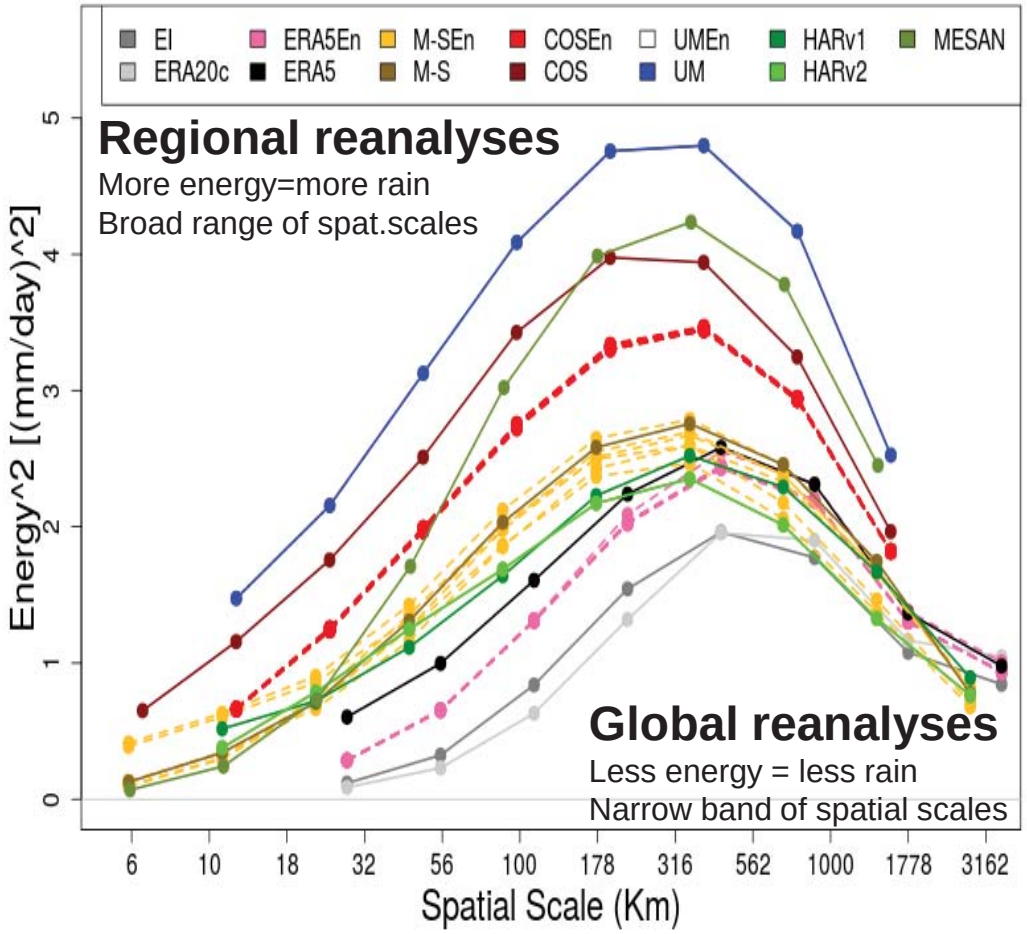
➔ Assess scale structure

➔ Bias, error and skill on different scales

Refrerences: Casati et al. (2004), Casati (2010)

Wavelet: Europe

no regridding
time period (model-dependent): 2000-2016
days with more than 5% of the domain with > 1 mm/d

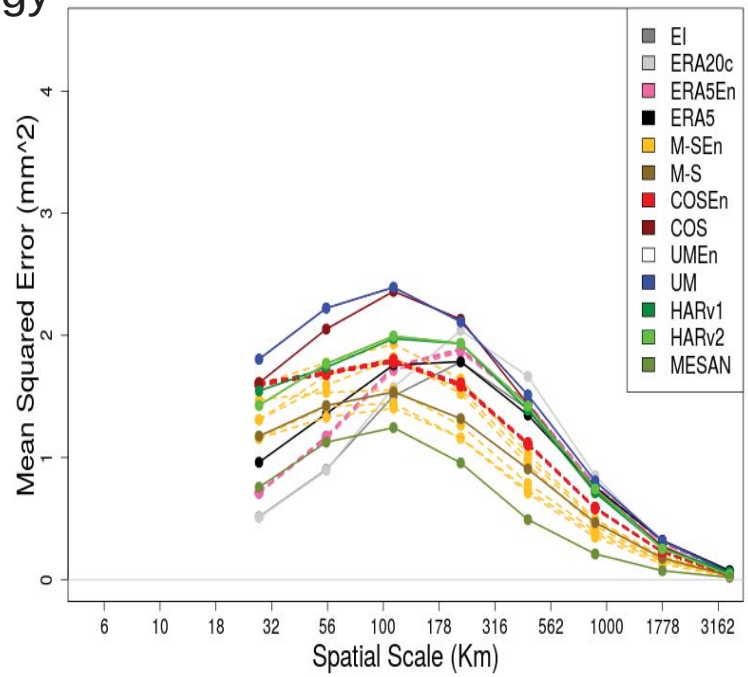


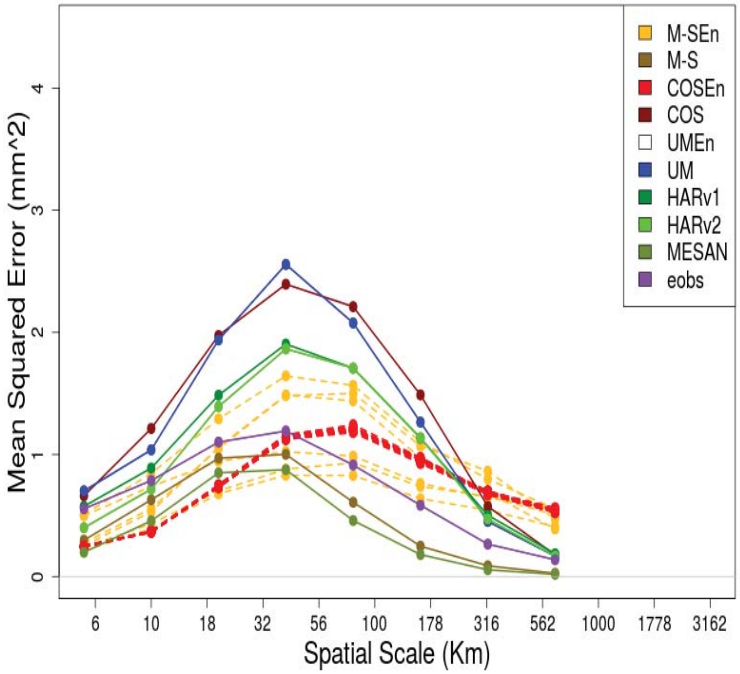
Mean Energy² as a function of the spatial scale (i.e. resolution)

Mean squared error (MSE)

RRAs show greater MSE for smaller spat.scales, but they also have more energy

MSE peaks are 32-56 Km
Ens differs from det

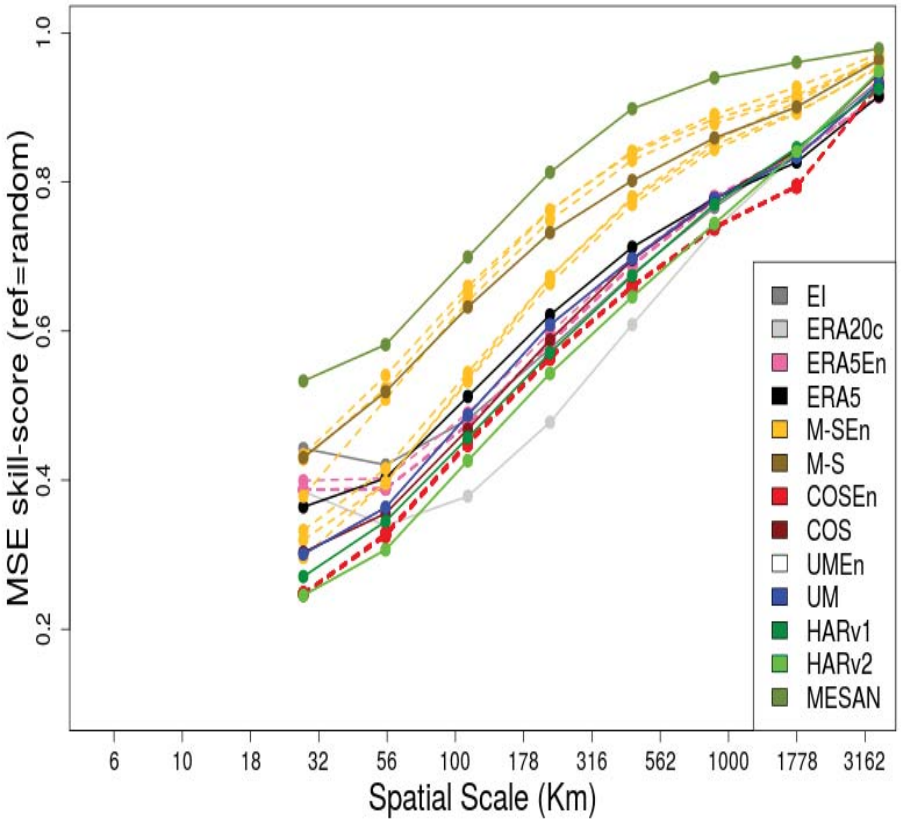


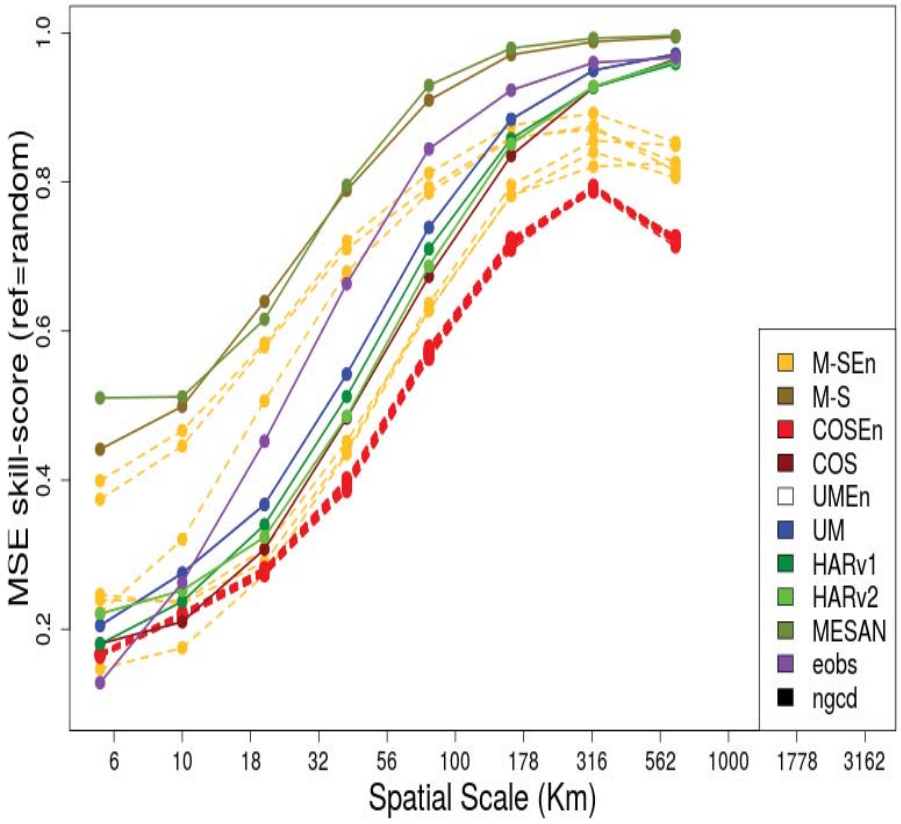


Mean squared error (MSE)

European domain
25km regridding
E-Obs reference

Fennoscandia domain
5km regridding
NGCD reference





Pan-Alpine Probabilistic Dataset

Area-mean precipitation over hydrological units in the Alps

Same data as for APGD

100 ensemble members

534 hydrological units,

- at four hierarchical scales
- 325 elementary units (EEA)

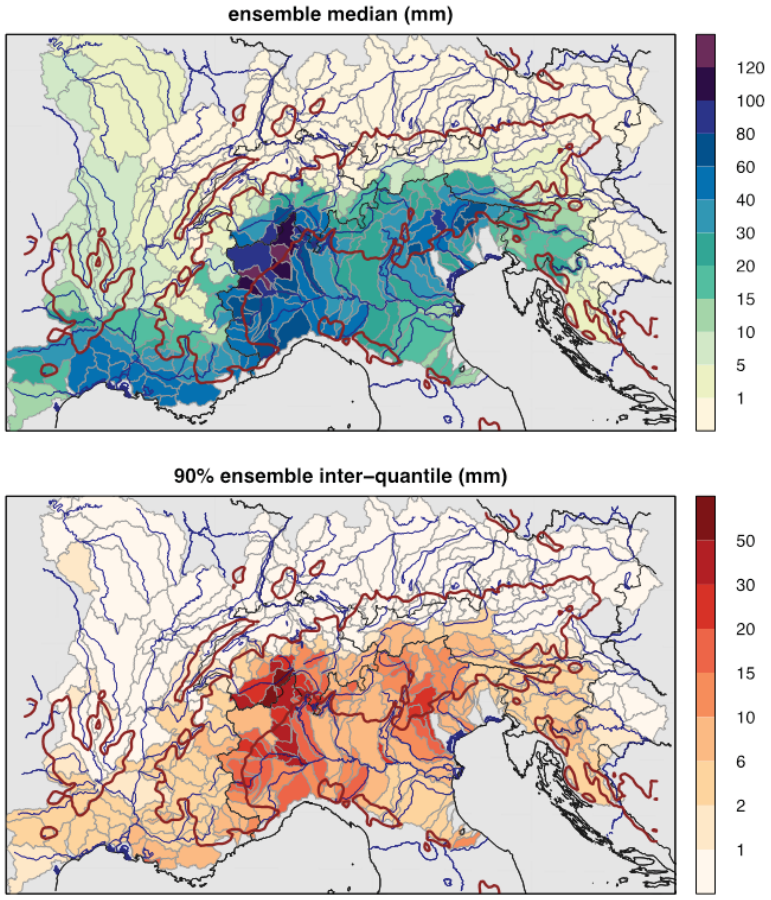
consistent within 68 super-units

daily, 1971-2008 (in process)

1981-1985, 2000-2008 processed

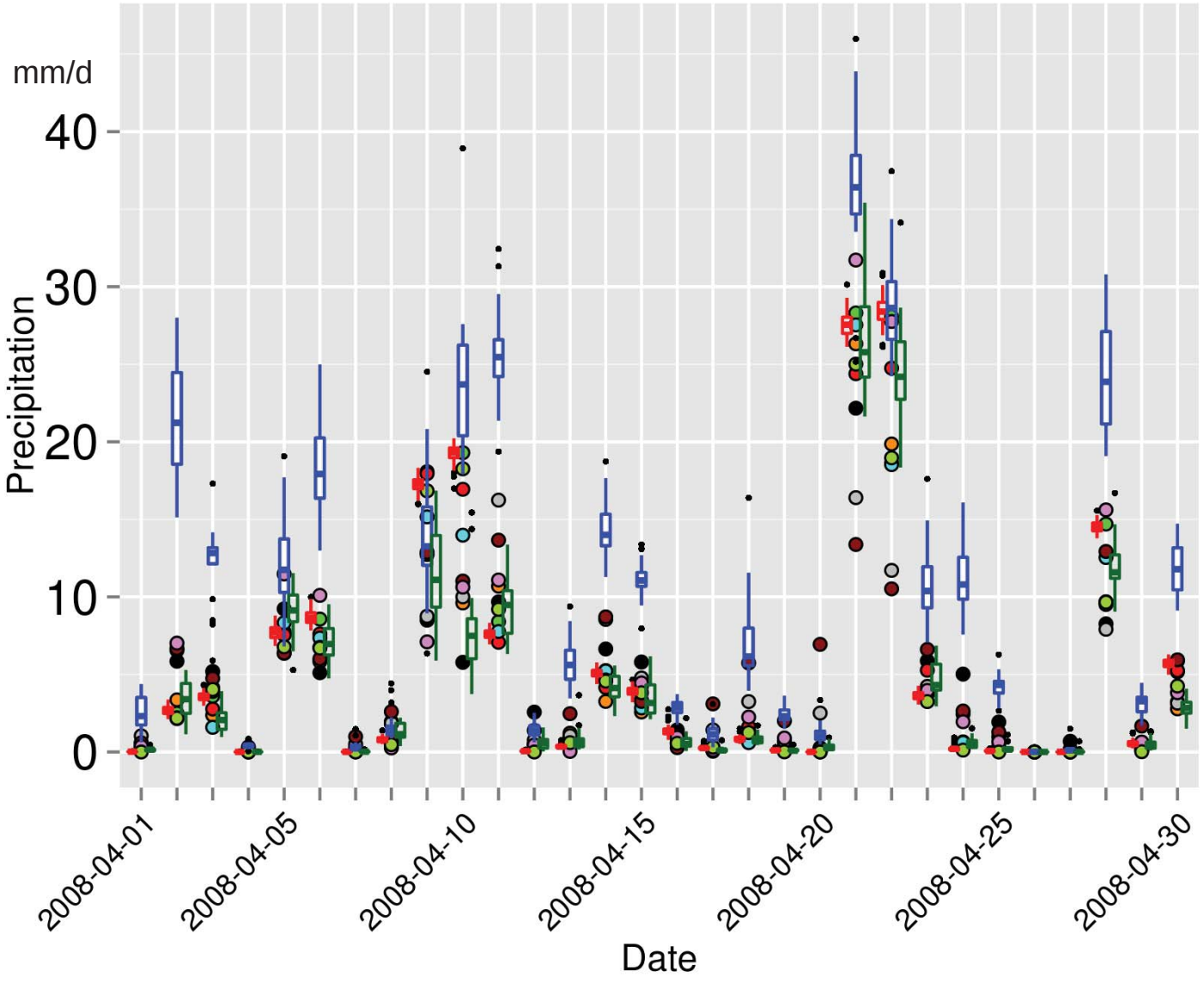
→ **APGDEns**

2008.11.04



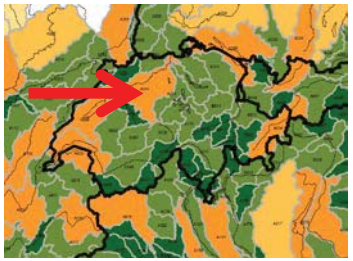
Daily precipitation

Aare catchment (part), April 2008



APGD-ENS
UKMO-ENS
COSMO-ENS

APGD
COSMO-REA6
HARMONIE
MESAN
MESCAN
ERAINT
ERA20C
UKMO
E-Obs



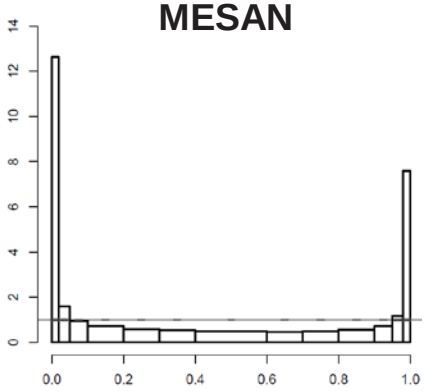
Rank histogramm

2006-2008 (25 km grid), APGD_ens reference

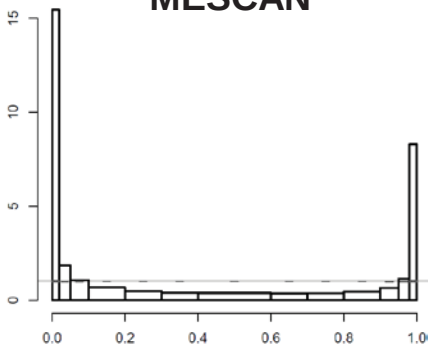
325 polygons (A polygons), only when all members >= 1mm/d precipitation)

Norwegian Meteorological Institute

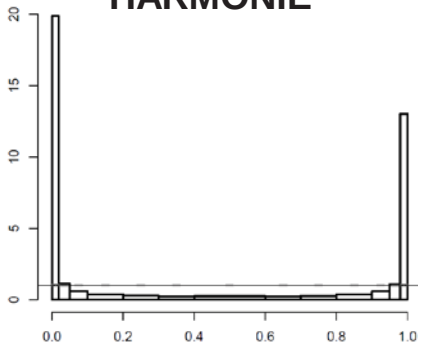
MESAN



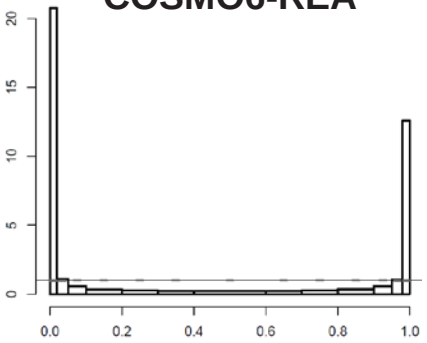
MESCAN



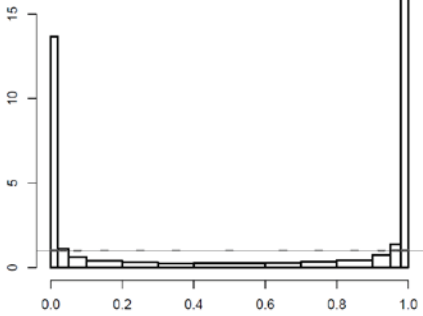
HARMONIE



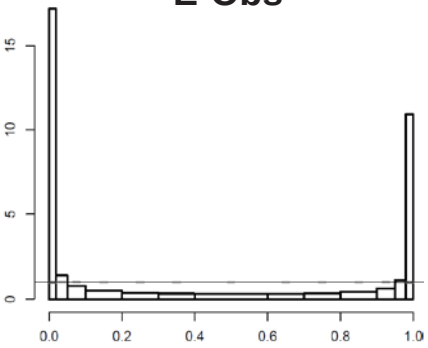
COSMO6-REA



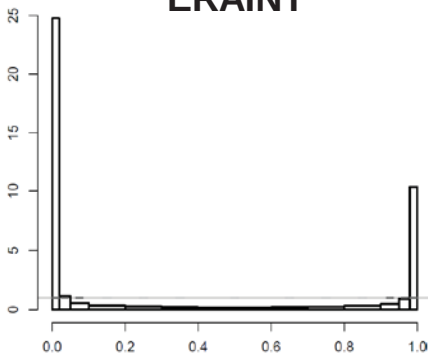
UKMO



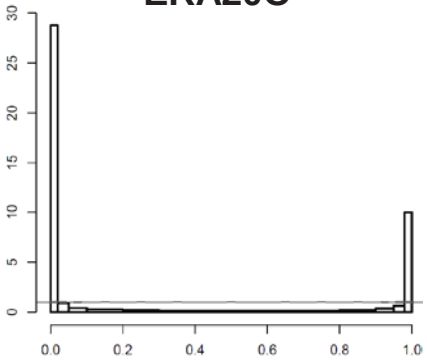
E-Obs



ERAINT



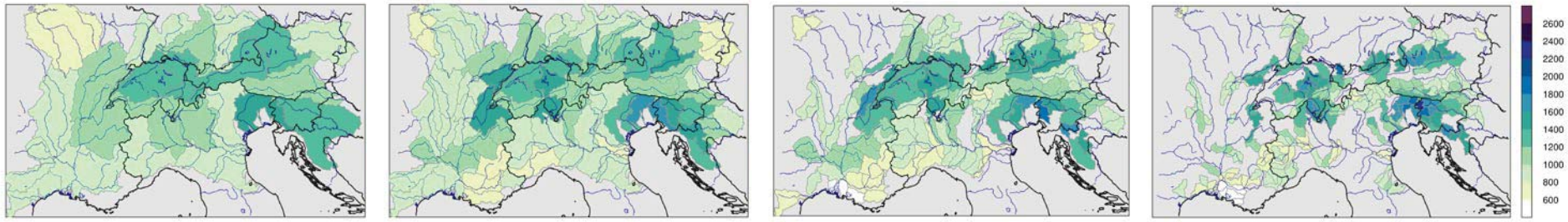
ERA20C



Mean annual precipitation

2005-2008
25 km grid
Catchments

APGDEns

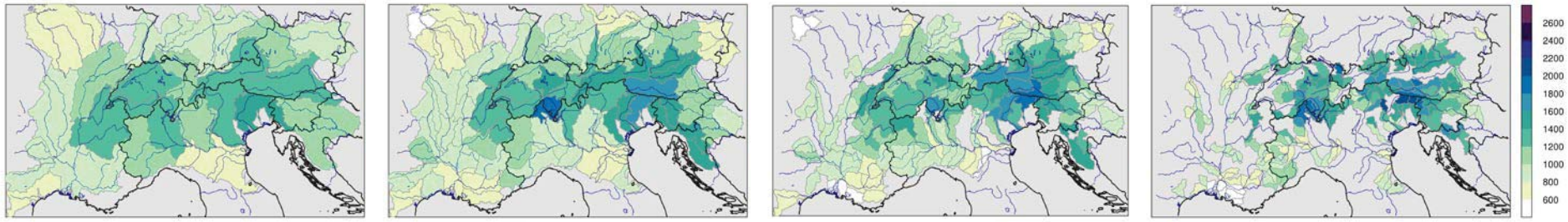


Scale A
14‘000-44‘000 km²

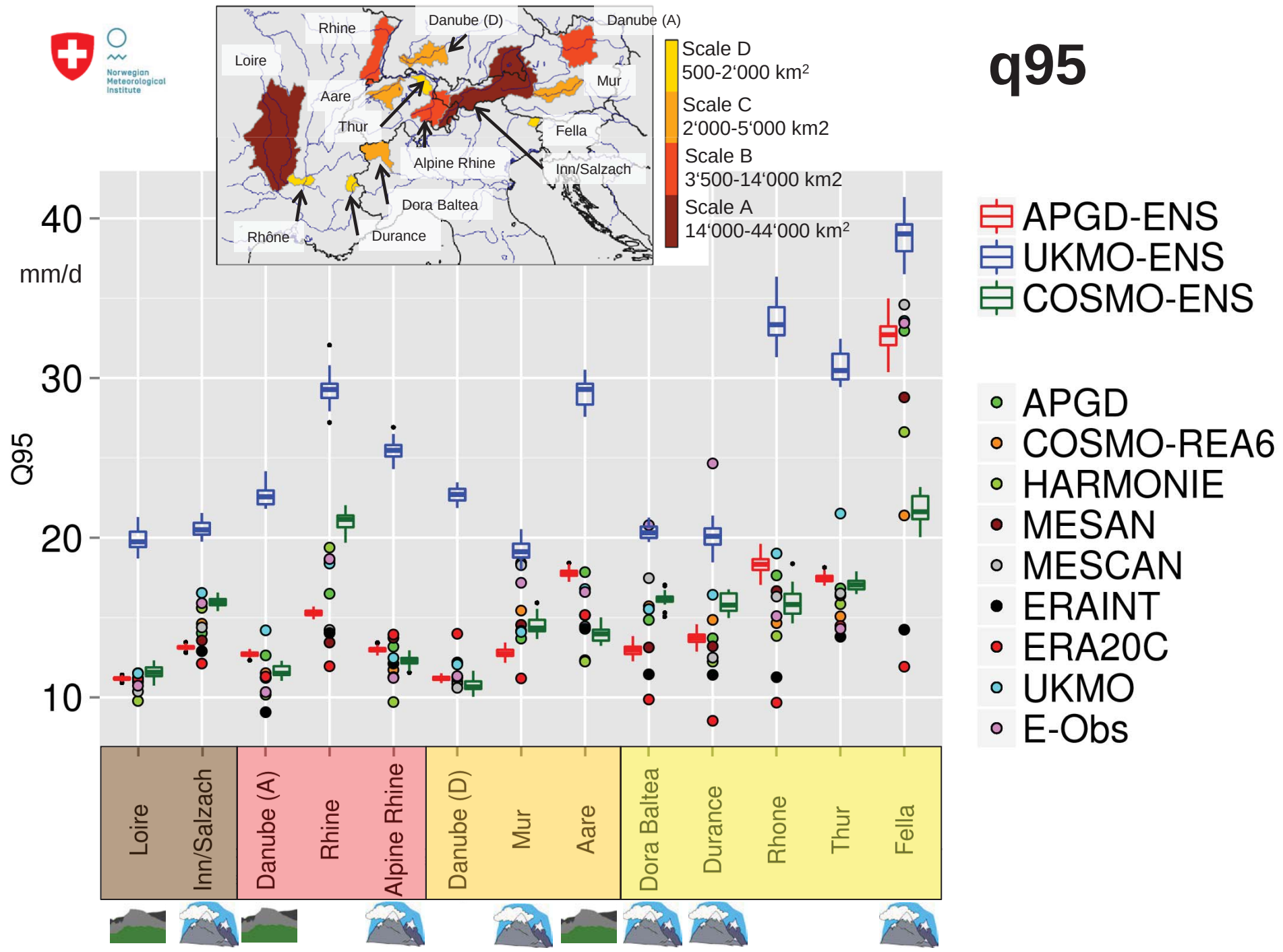
Scale B
3‘500-14‘000 km2

Scale C
2‘000-5‘000 km2

Scale D
500-2‘000 km²



MESCAN


Norwegian Meteorological Institute
Rhine
Danube (D)
Danube (A)
Loire
Aare
Thur
Mur
Fella
Alpine Rhine
Inn/Salzach
Dora Baltea
Rhône
Durance
Scale D
500-2‘000 km2
Scale C
2‘000-5‘000 km2
Scale B
3‘500-14‘000 km2
Scale A
14‘000-44‘000 km2
q95
40
mm/d
30
20
10
Q95
Loire
Inn/Salzach
Danube (A)
Rhine
Alpine Rhine
Danube (D)
Mur
Aare
Dora Baltea
Durance
Rhone
Thur
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APGD-ENS
UKMO-ENS
COSMO-ENS
APGD
COSMO-REA6
HARMONIE
MESAN
MESCAN
ERAINT
ERA20C
UKMO
E-Obs

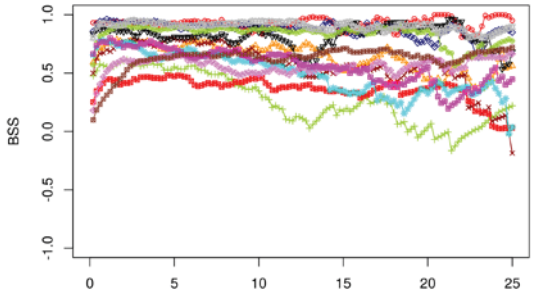
BSS

BRIER $\frac{1}{n}\sum_i^n (Y_i - O_i)^2$

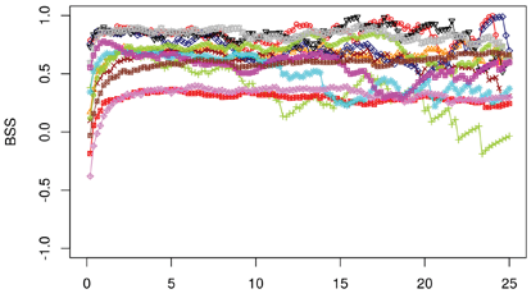
(forecasted/observed event probability)

2006-2008
25 km grid
APGD_Ens «ref»

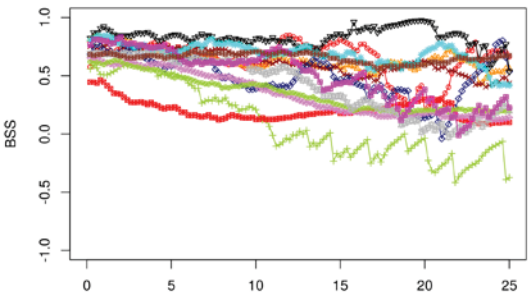
MESAN



MESCAN

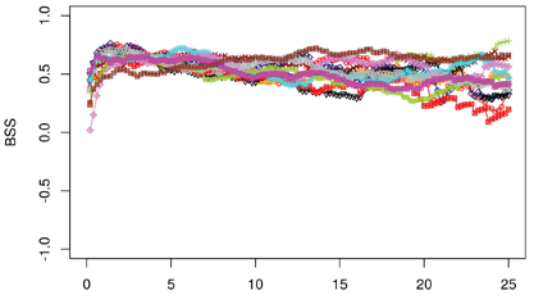


E-Obs

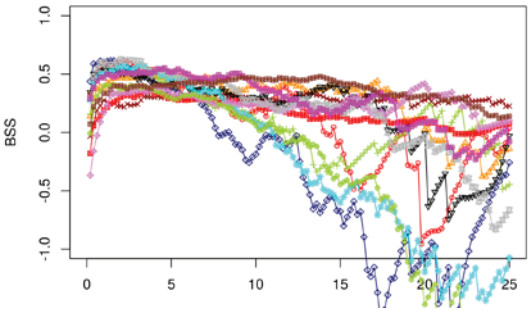


- Loire
- Inn/Salzach
- Danube (A)
- Rhine
- Alpine Rhine
- Danube (D)
- Mur
- Aare
- Dora Baltea
- Durance
- Rhone
- Thur
- Fella

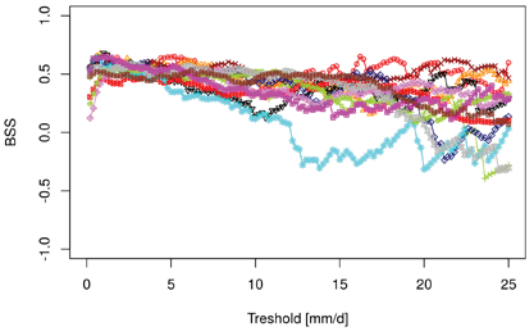
UKMOdet



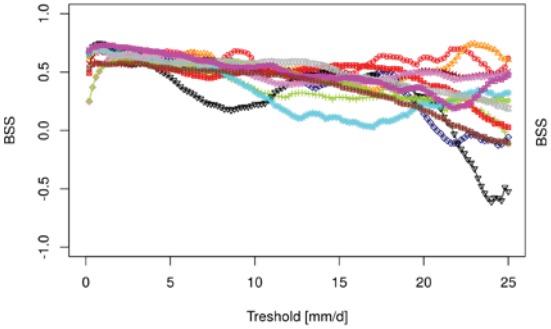
HARMONIE v1



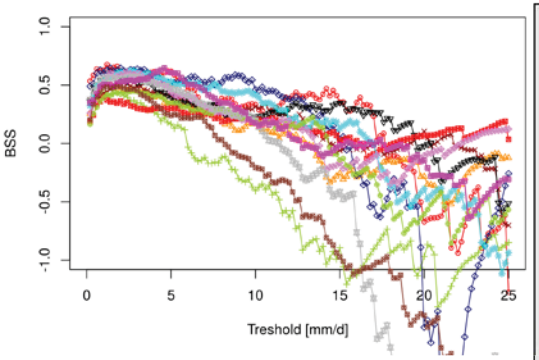
COSMO6-REA

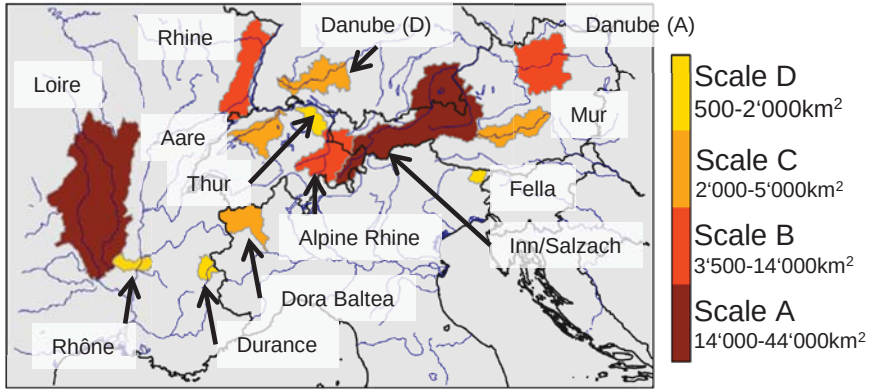


COSMOEns



ERAINT



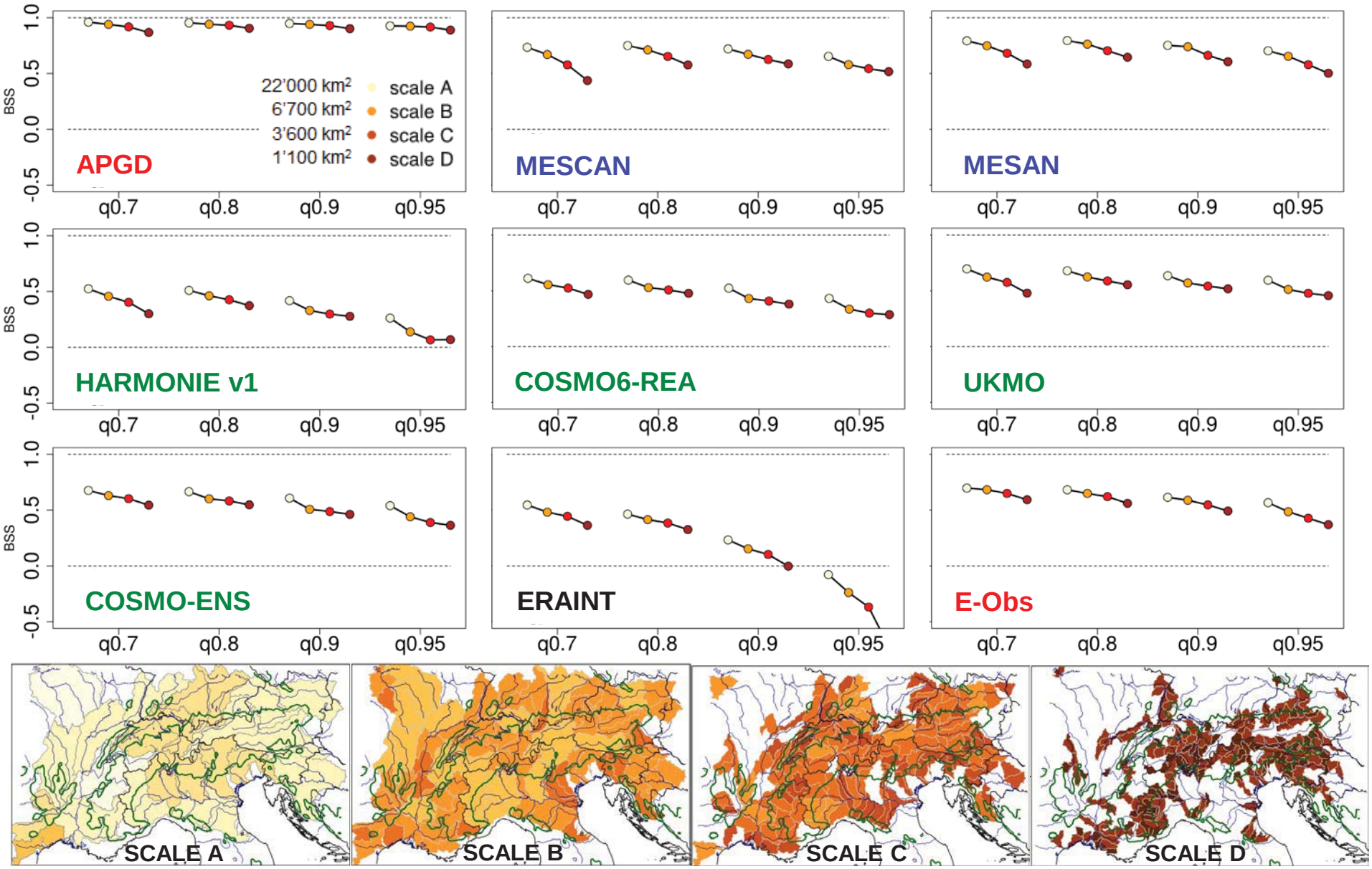


BSS vs scale

$$\frac{1}{n}\sum_{i}^{n}(Y_i - O_i)^2$$
(forecasted/observed event probability)

Gridding
Regional Rean.
Downscaling
Global Rean.

2006-2008
25 km grid
APGD_Ens ref

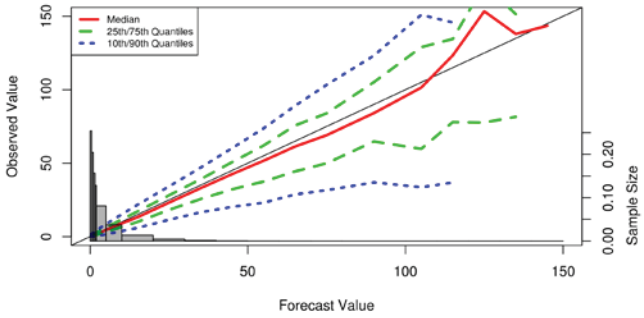


Conditional quantile plots

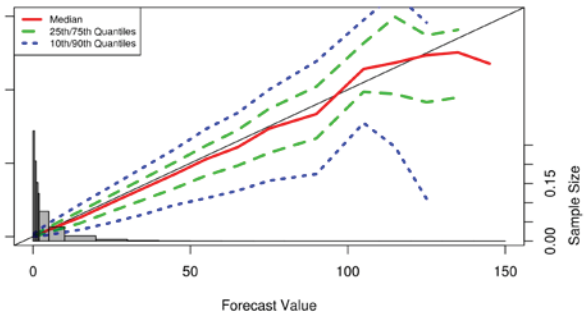
2005-2008
25 km grid
APGD ref

Norwegian Meteorological Institute

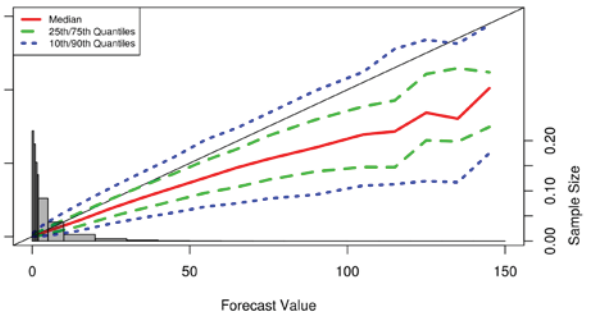
MESAN (EURO4M)



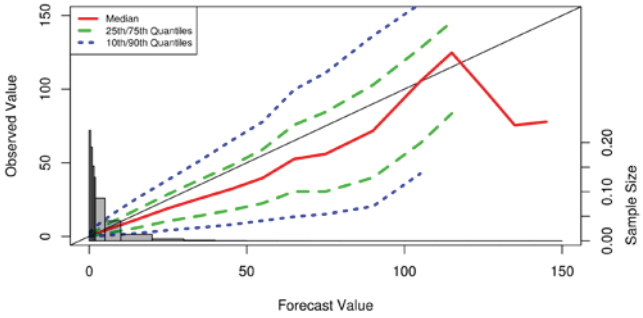
MESCAN



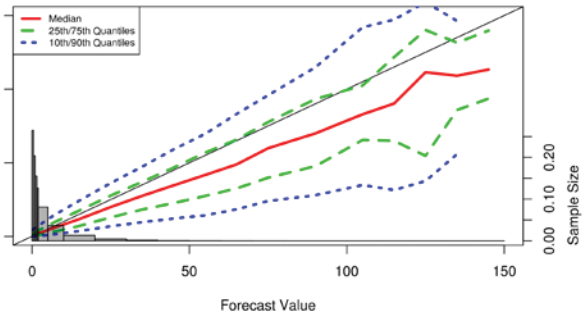
UKMO det



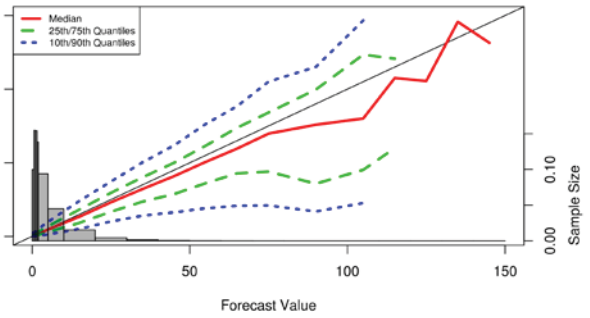
HARMONIE v1



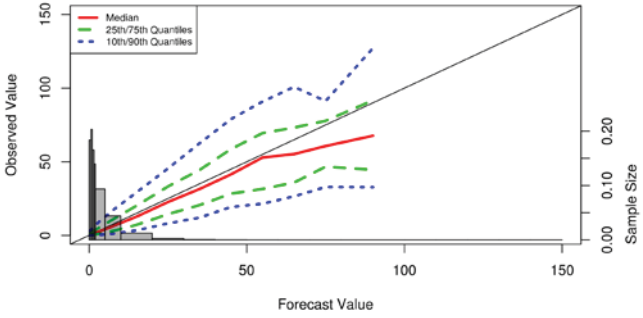
COSMO6-REA



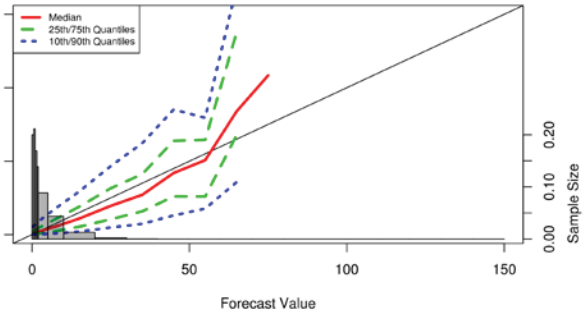
E-Obs



ERAINT



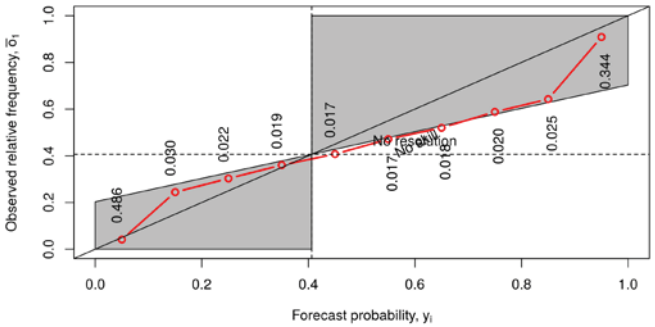
ERA20C



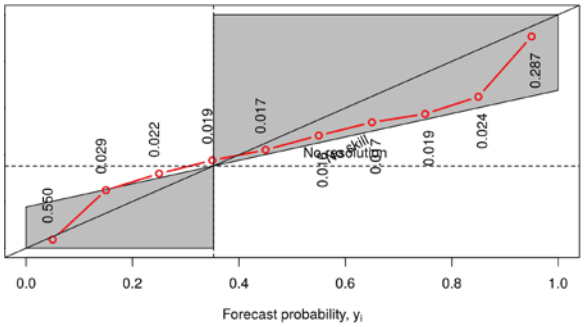
Attribute diagramm

1971-2008
25 km grid
APGD ref

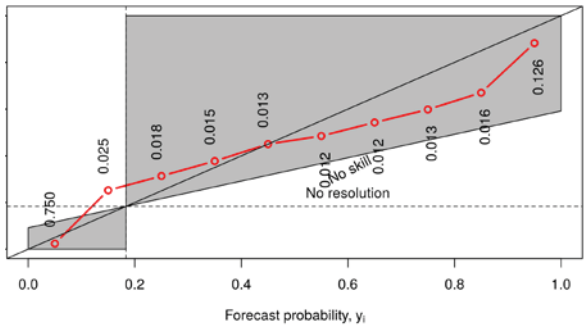
COSMOEns 0.5mm/d



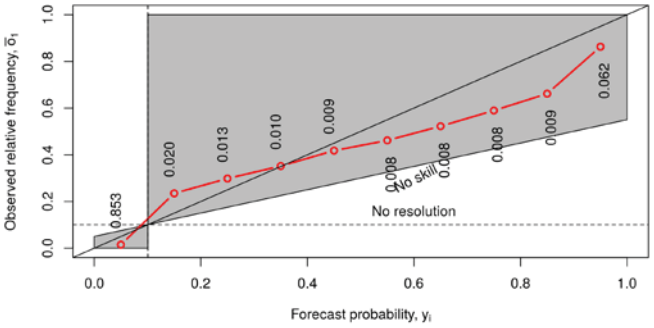
COSMOEns 1mm/d



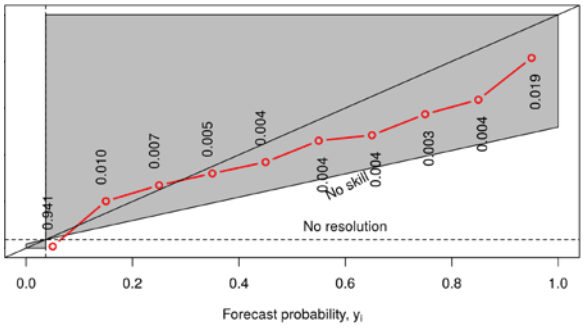
COSMOEns 5mm/d



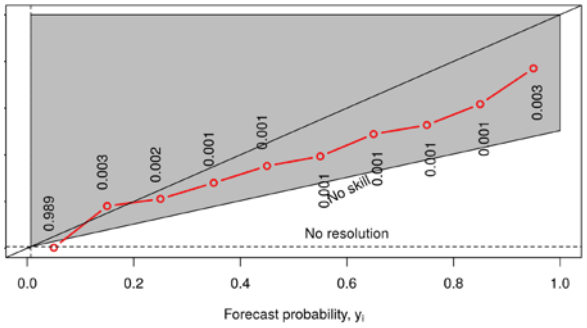
COSMOEns 10mm/d



COSMOEns 20mm/d

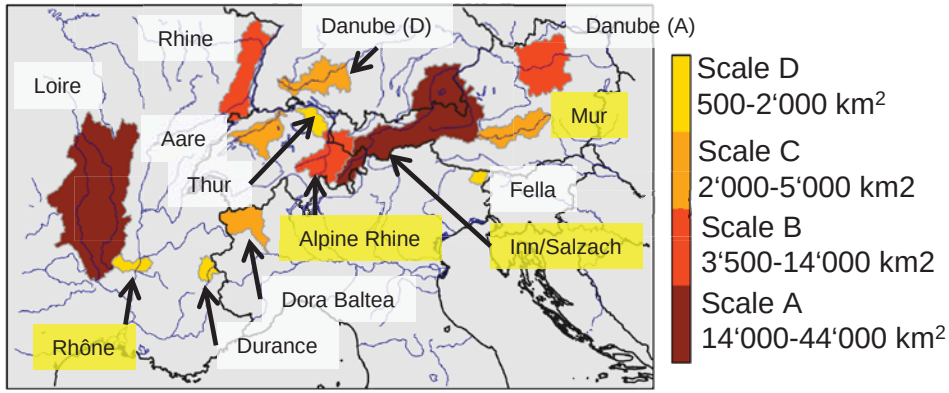


COSMOEns 40mm/d

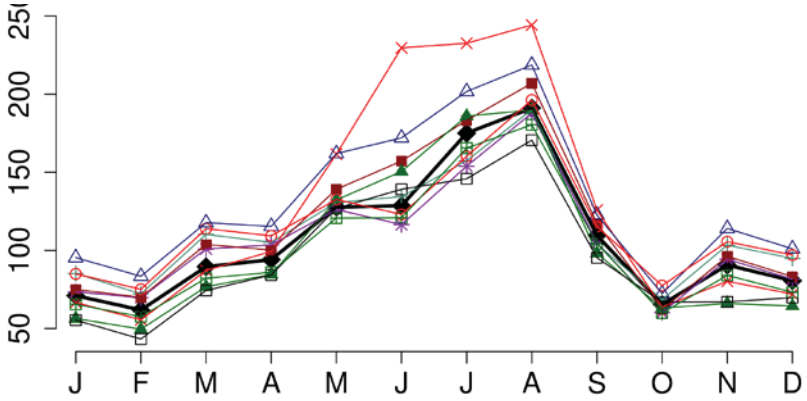


Yearly cycle

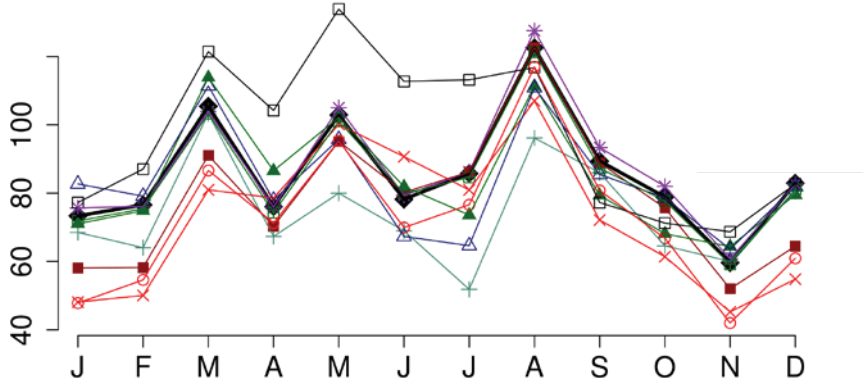
Monthly mean total precipitation
2005-2008 (25 km grid)



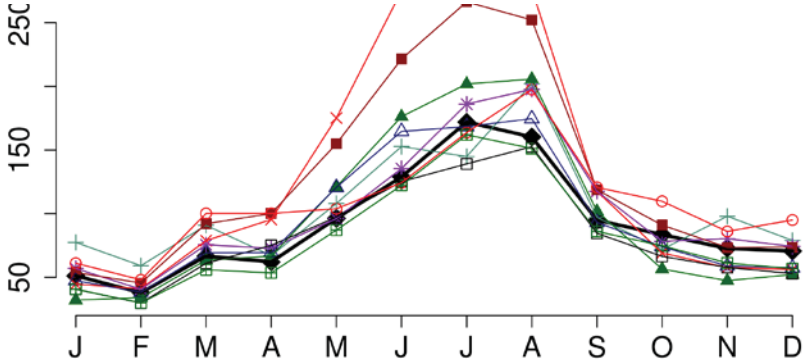
Inn/Salzach



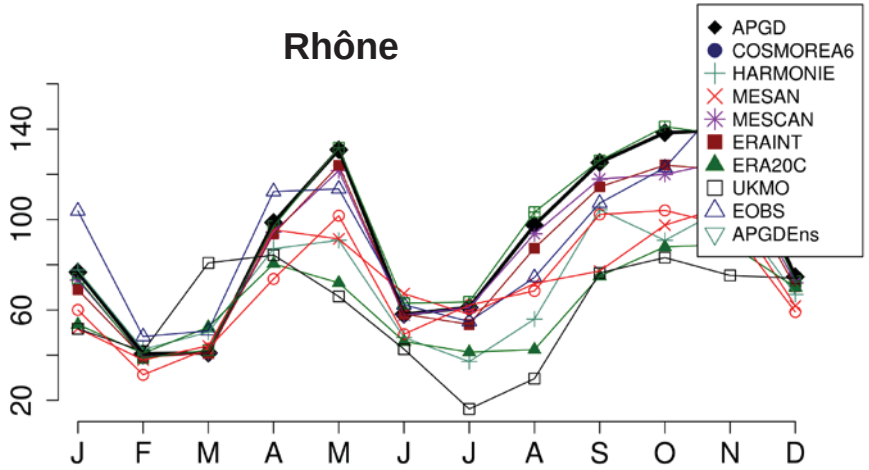
Alpine Rhine



Mur

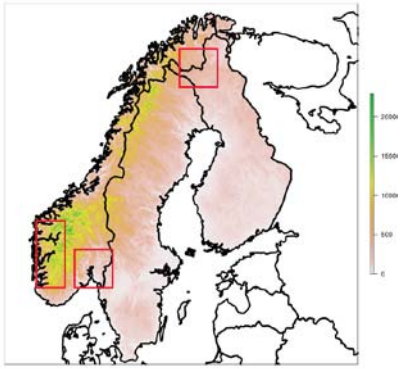


Rhône

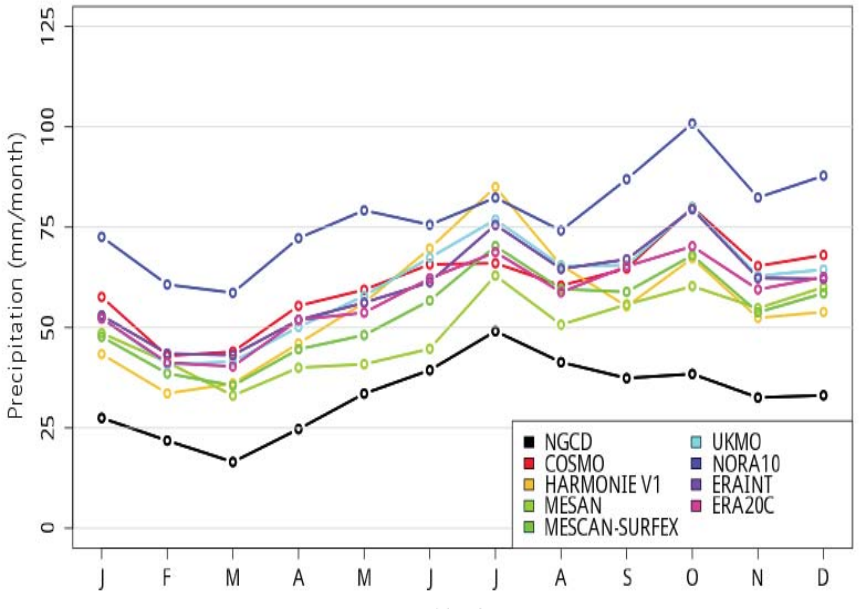


Yearly cycle

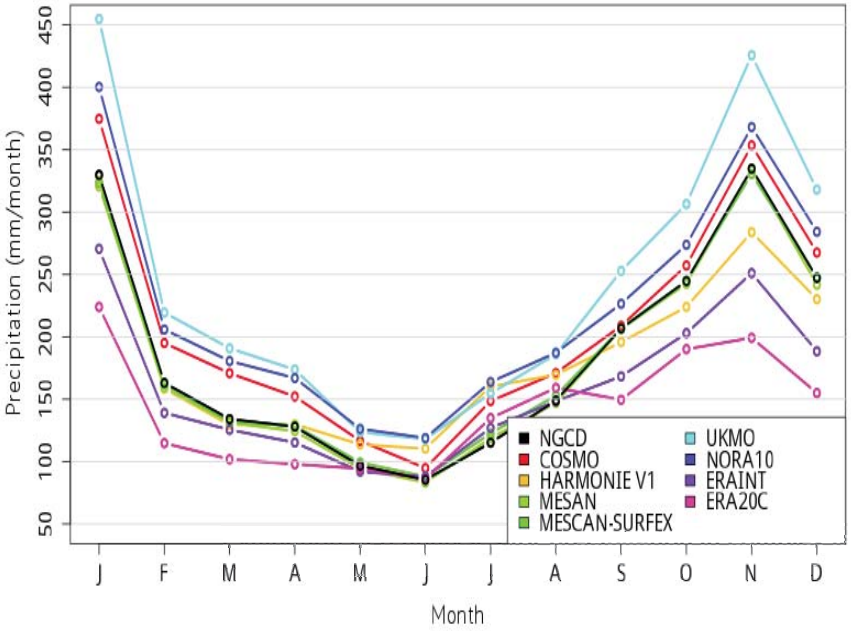
Monthly mean total precipitation
2005-2008 (25 km grid)



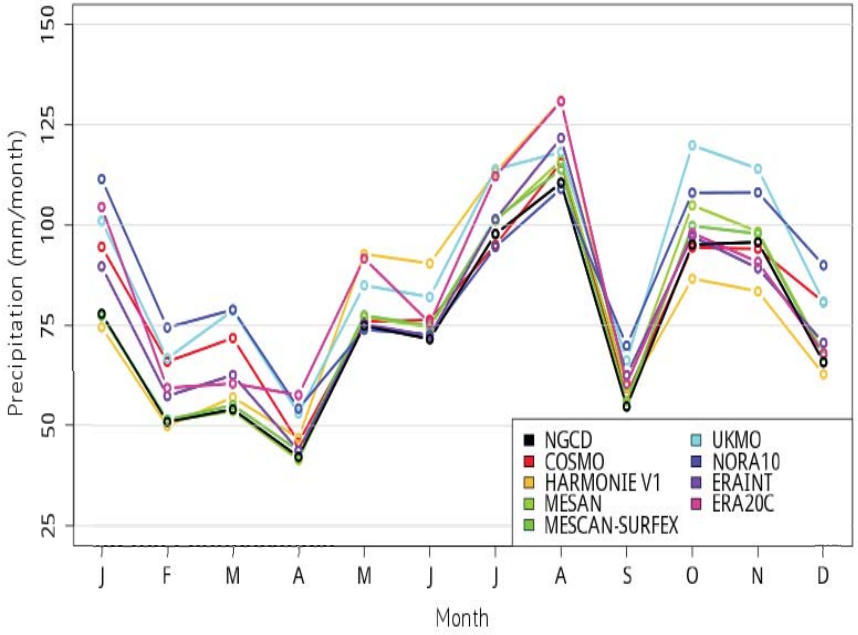
Lapland



West coast

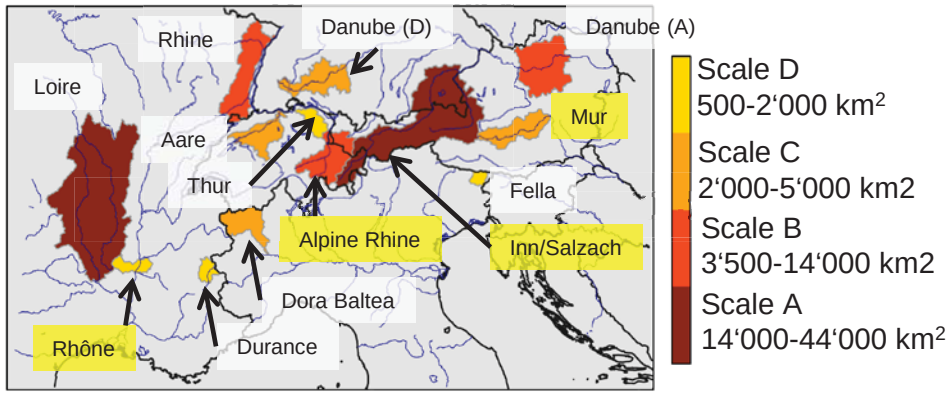


Oslo Area

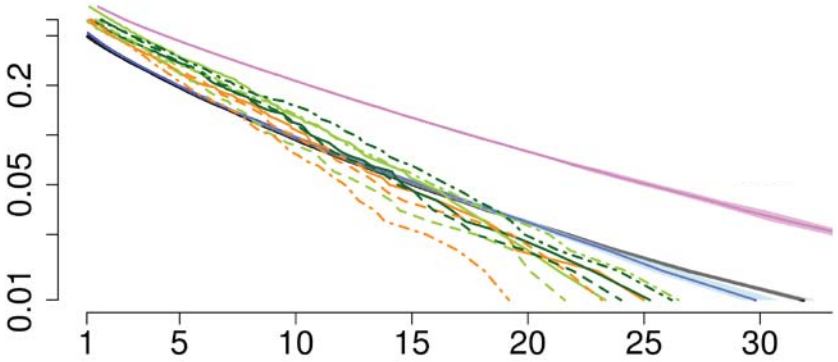


Frequency distribution functions

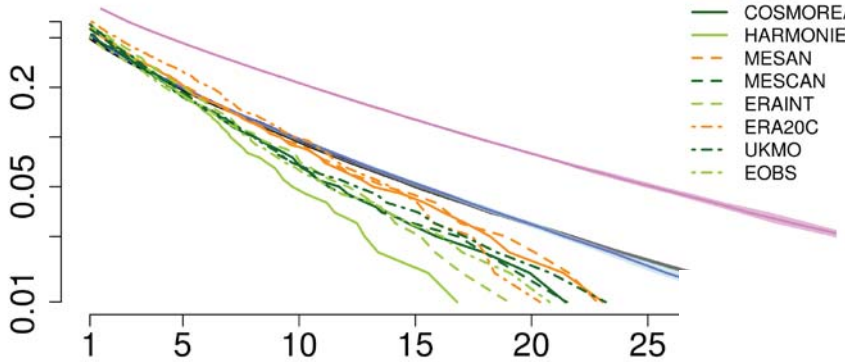
2005-2008 (25 km grid)



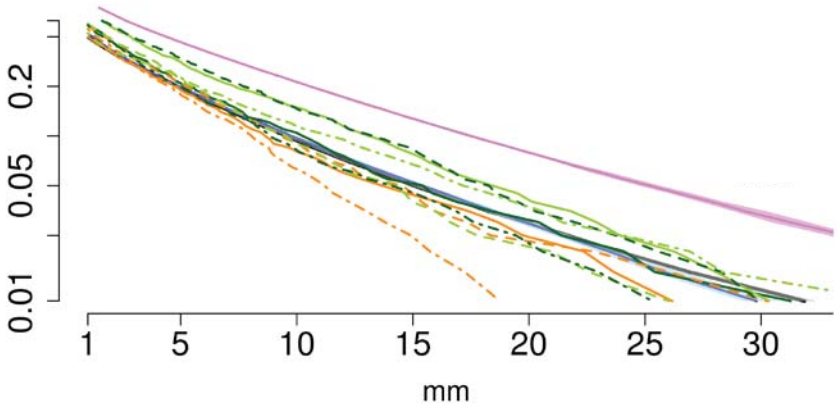
Inn/Salzach



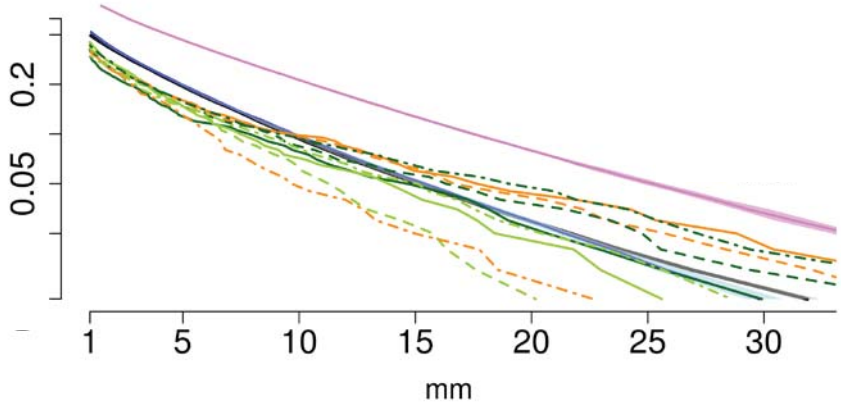
Alpine Rhine



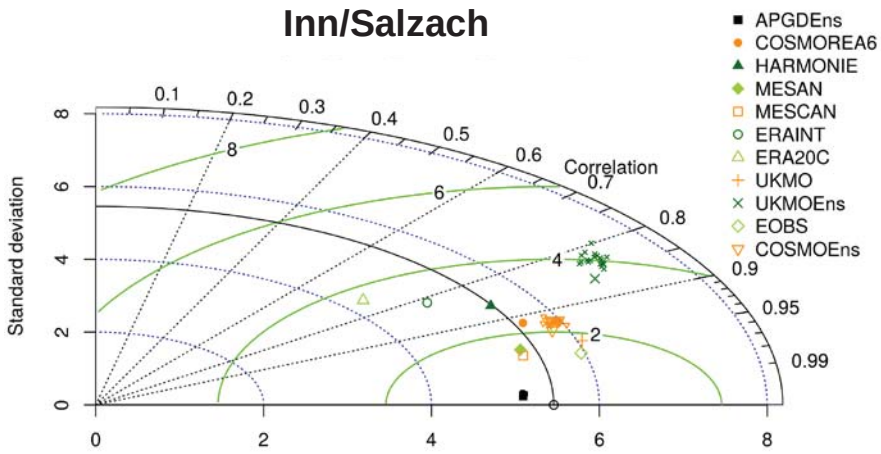
Mur

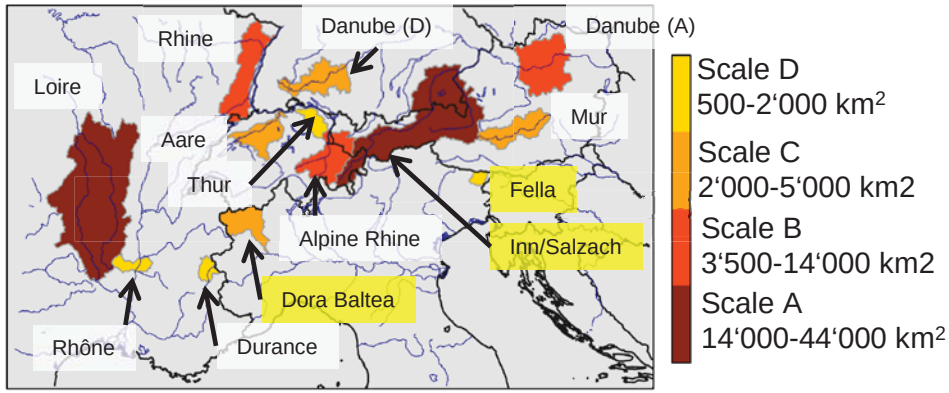


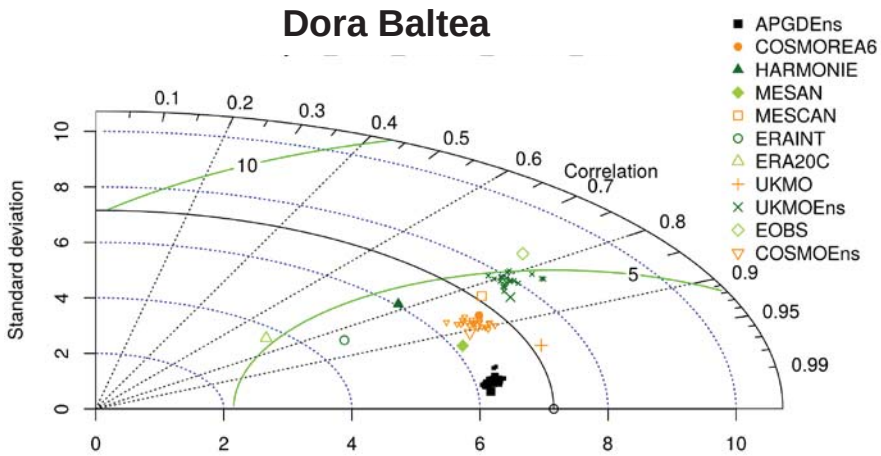
Rhône

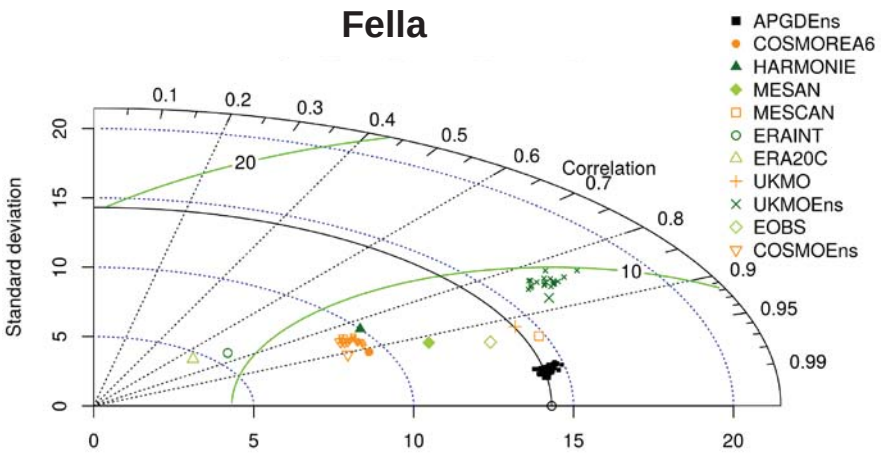


Taylor diagram 2005-2008 (25 km grid), APGD reference







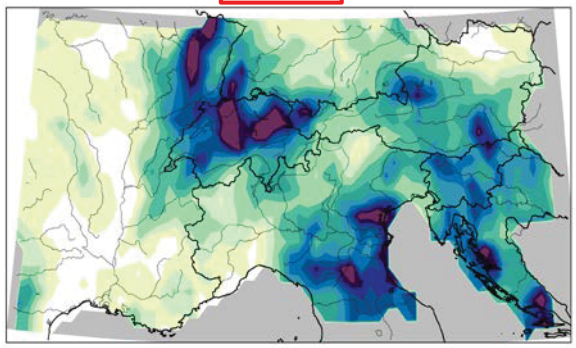


Precipitation sum 16-18.9.2006

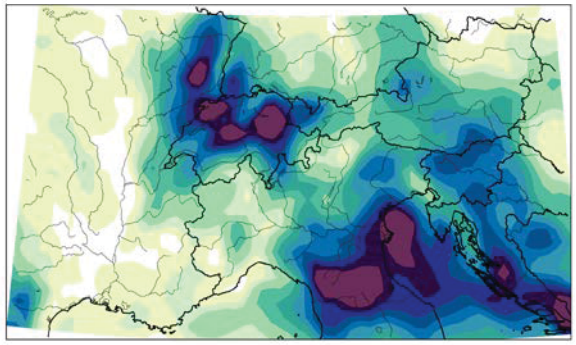
25 km grid

Norwegian Meteorological Institute

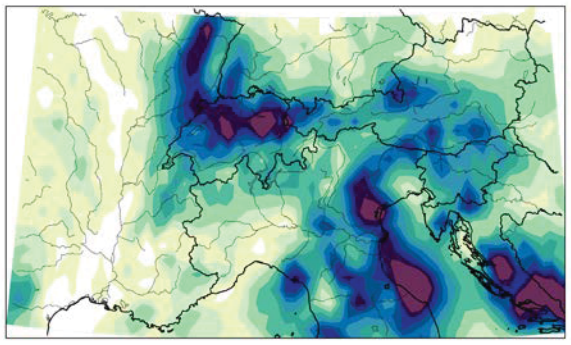
APGD



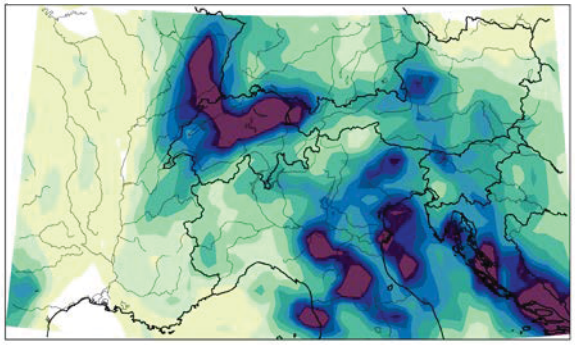
MESAN



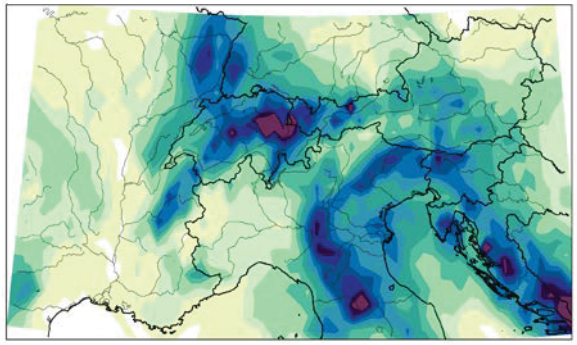
MESCAN



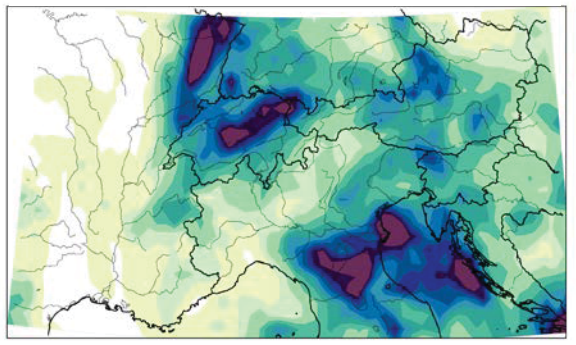
UKMO

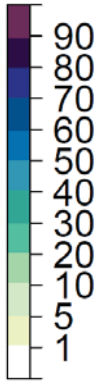


HARMONIE

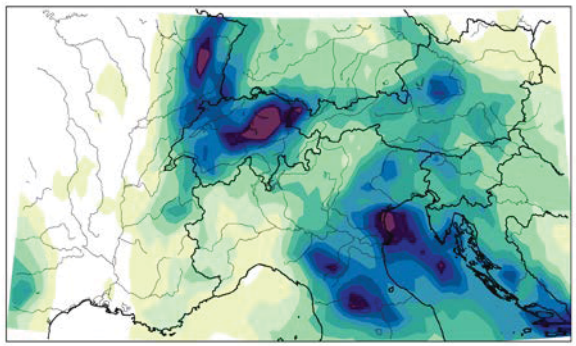


COSMO6-REA

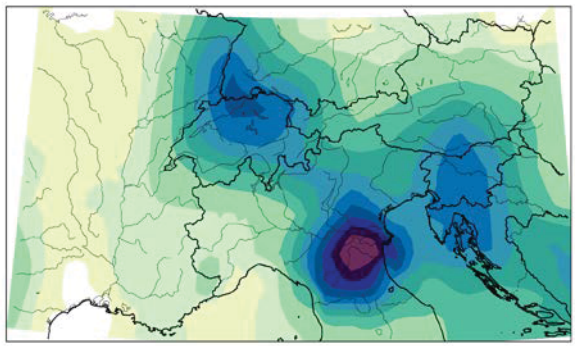




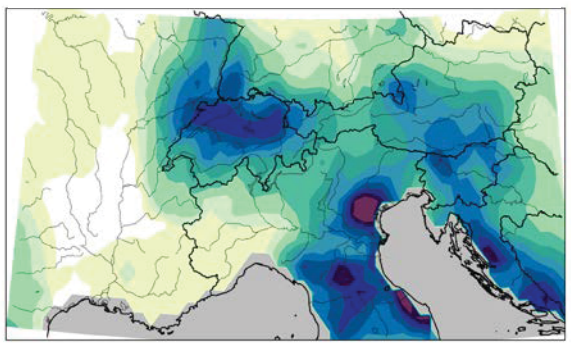
COSMO-ENS (ens. median)



ERAINT



E-OBS



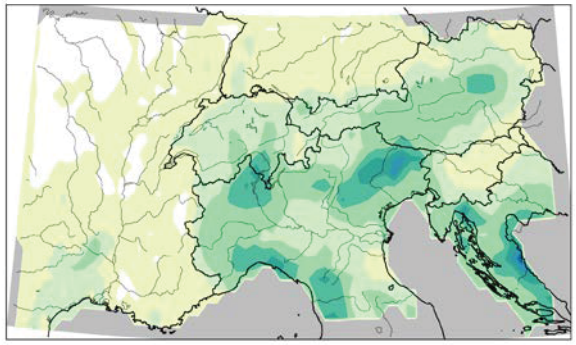
RMSE

2005-2008
25 km grid

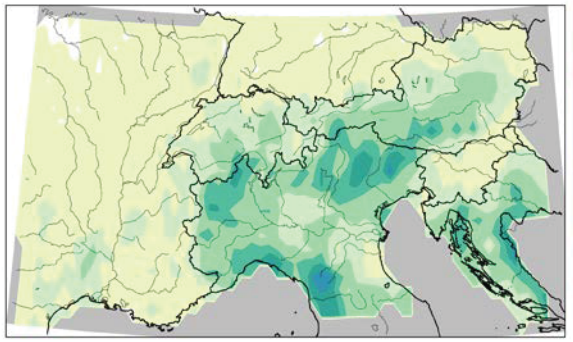
APGD reference

$$\text{RMSE}=\sqrt{\frac{1}{n}\sum_i^n (y_i - o_i)^2}$$

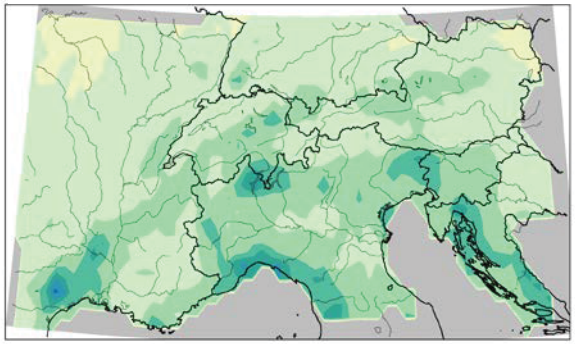
MESAN (EURO4M)



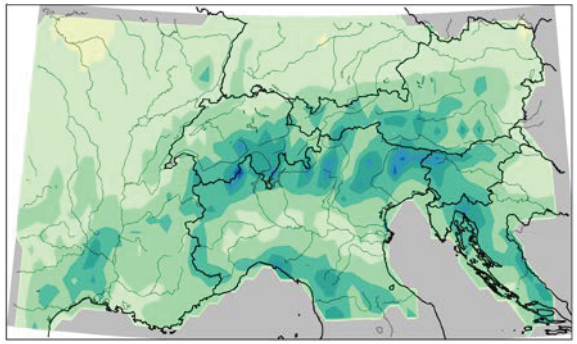
MESCAN



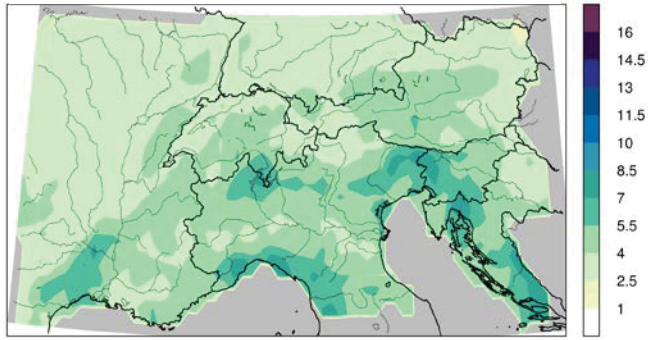
UKMO det



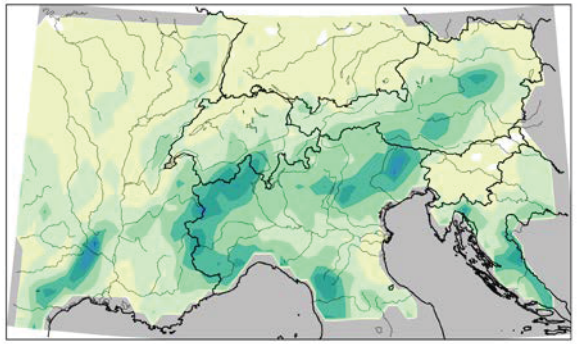
HARMONIE v1



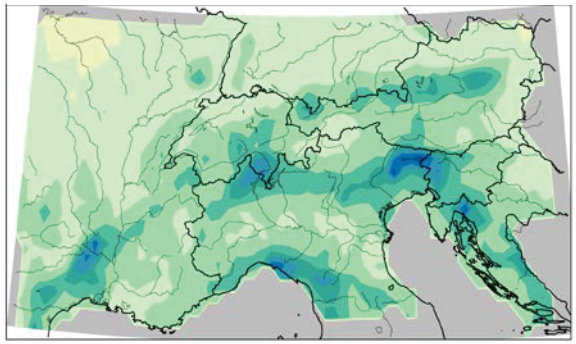
COSMO6-REA



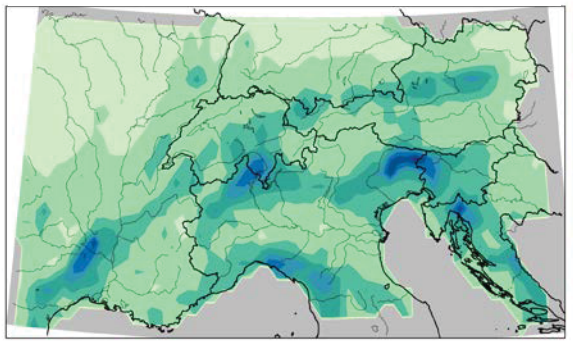
E-Obs



ERAINT



ERA20C



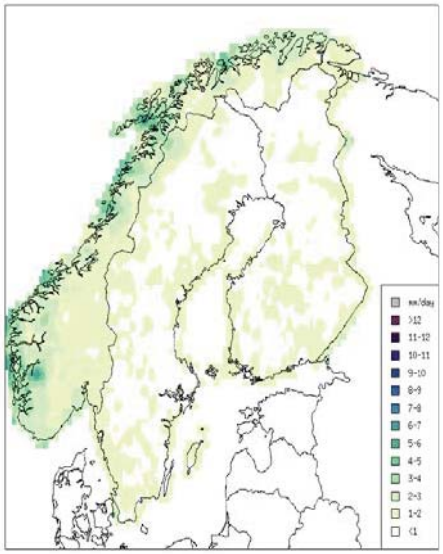
RMSE

2005-2008
25 km grid

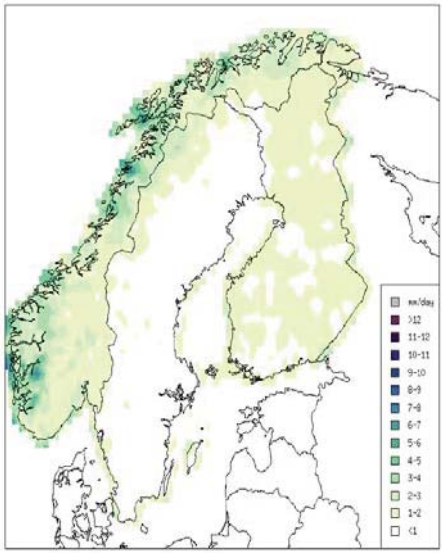
NGCD reference

RMSE= $\sqrt{\frac{1}{n}\sum_i^n (y_i - o_i)^2}$

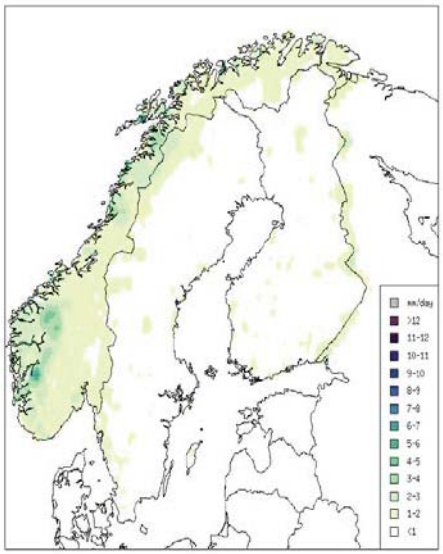
MESAN



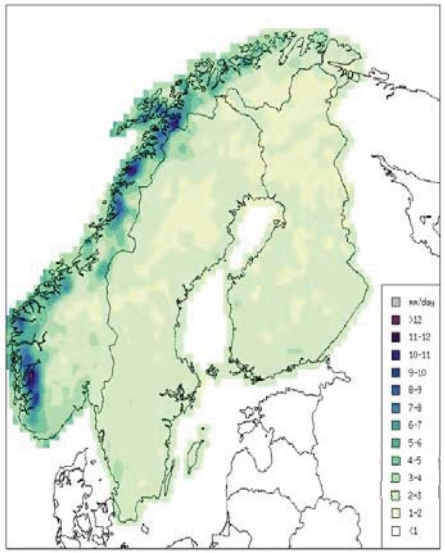
MESCAN



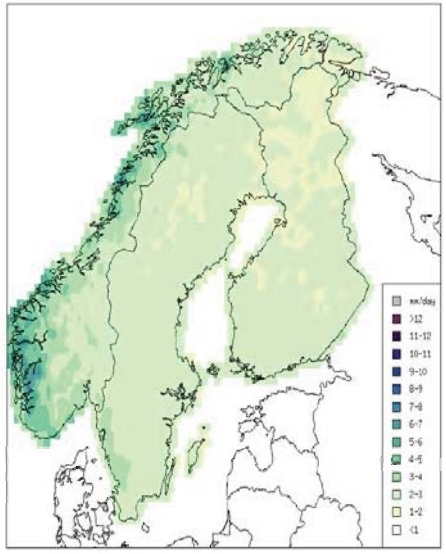
EOBS



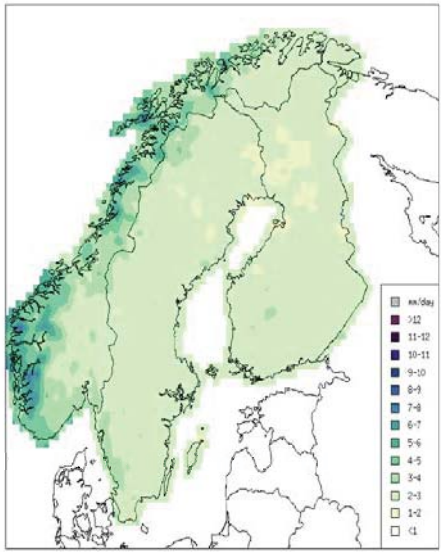
UKMO det



HARMONIE v1



COSMO6-REA



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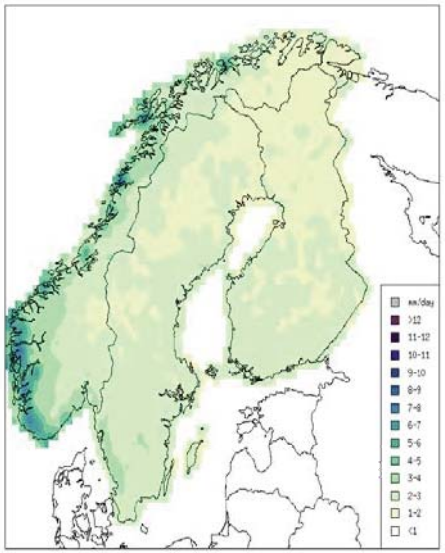

Conclusion

- **Regional reanalyses:**
  - **additional value compared to global reanalyses**
  - **tendency to overestimate precipitation amounts and frequency, especially in complex terrain (Alps, Norway)**
  - **regional reanalysis shows better small scale structures and performance than observational gridded datasets in region of low station density (except wet-day frequency)**
  - **Alps: COSMO6-REA and COSMO-ENS best performance.**
  - **Fennoscandia: HARMONIE best performance.**

- **Downscaling:**
  - **additional value in regions with dense station network**
  - **improvement especially for fraction of wet days**

- **Model error mostly bigger than uncertainty of the reference dataset (especially for days >10mm/d precipitation and global reanalyses)**
- **Scale dependent analyses: more information about the performance of the datasets depending on the application/scale of interest. Biggest differences from the reference and the lowest Brier skill score are found in complex topography, small catchment sizes and for higher precipitation amounts.**
- **Annual cycle is mostly well reproduced in all datasets.**