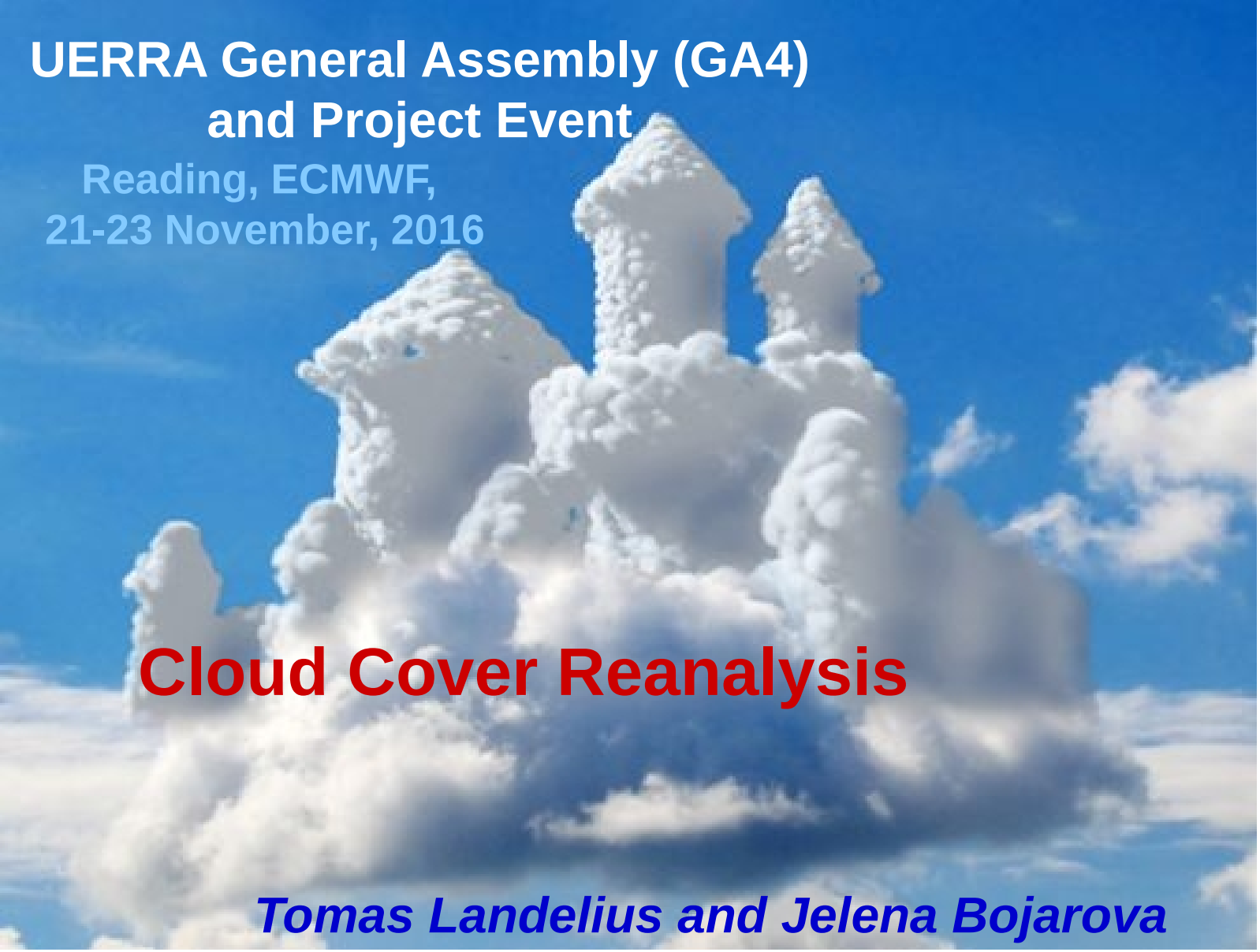

UERRA General Assembly (GA4)
and Project Event

Reading, ECMWF,
21-23 November, 2016

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Cloud Cover Reanalysis

Tomas Landelius and Jelena Bojarova

UERRA
Uncertainties in Ensembles of Regional ReAnalyses

Swedish Meteorological and Hydrological Institute

European cloud cover reanalysis using best available data at any given time

Purpose

– pan-European grided data set of cloud fraction for climate studies, validation of models and solar energy potential

Period

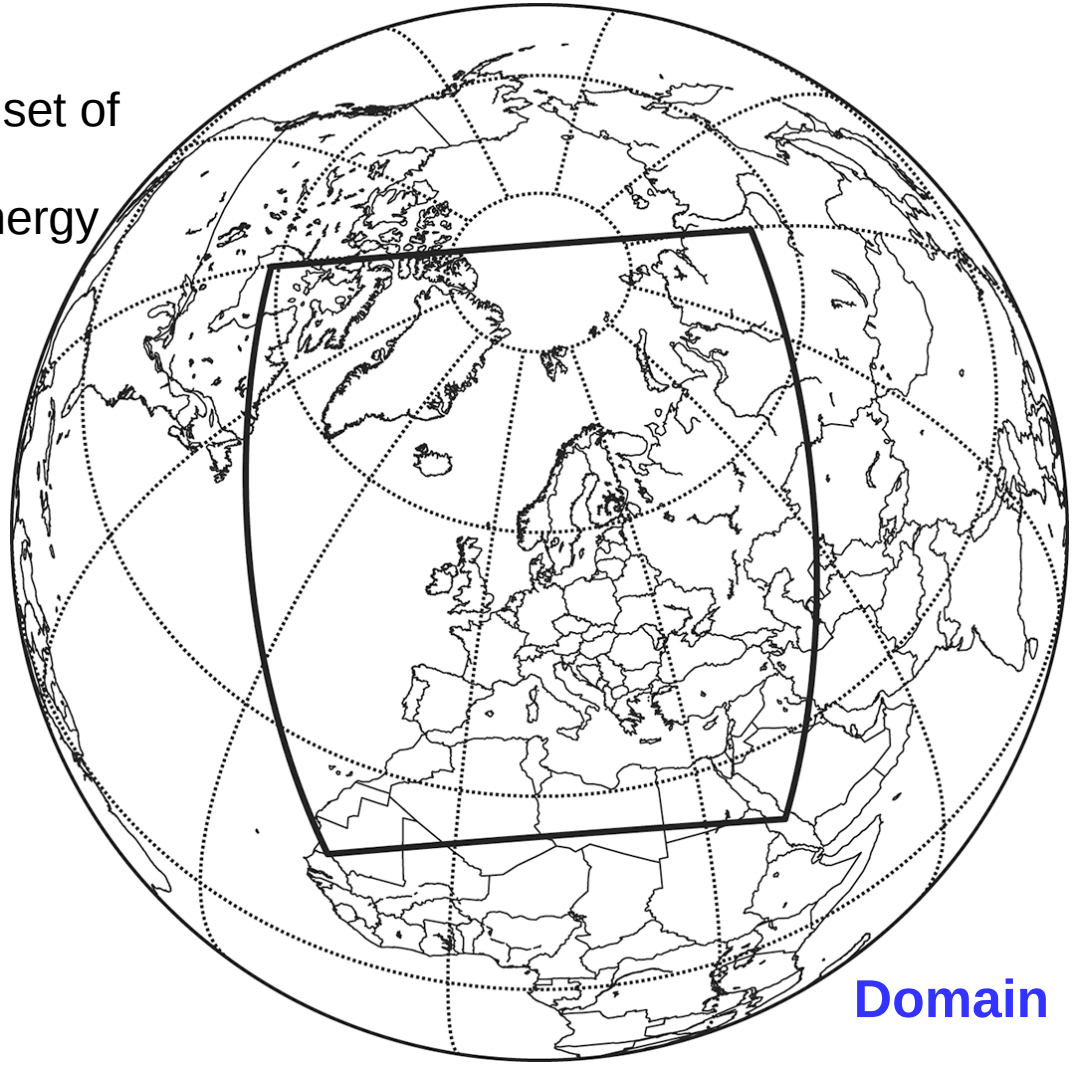
– 30 years reanalysis: 1982-2013

Horizontal resolution:

– 5.5 km MESAN EURO4M

Time resolution:

– Hourly



Domain

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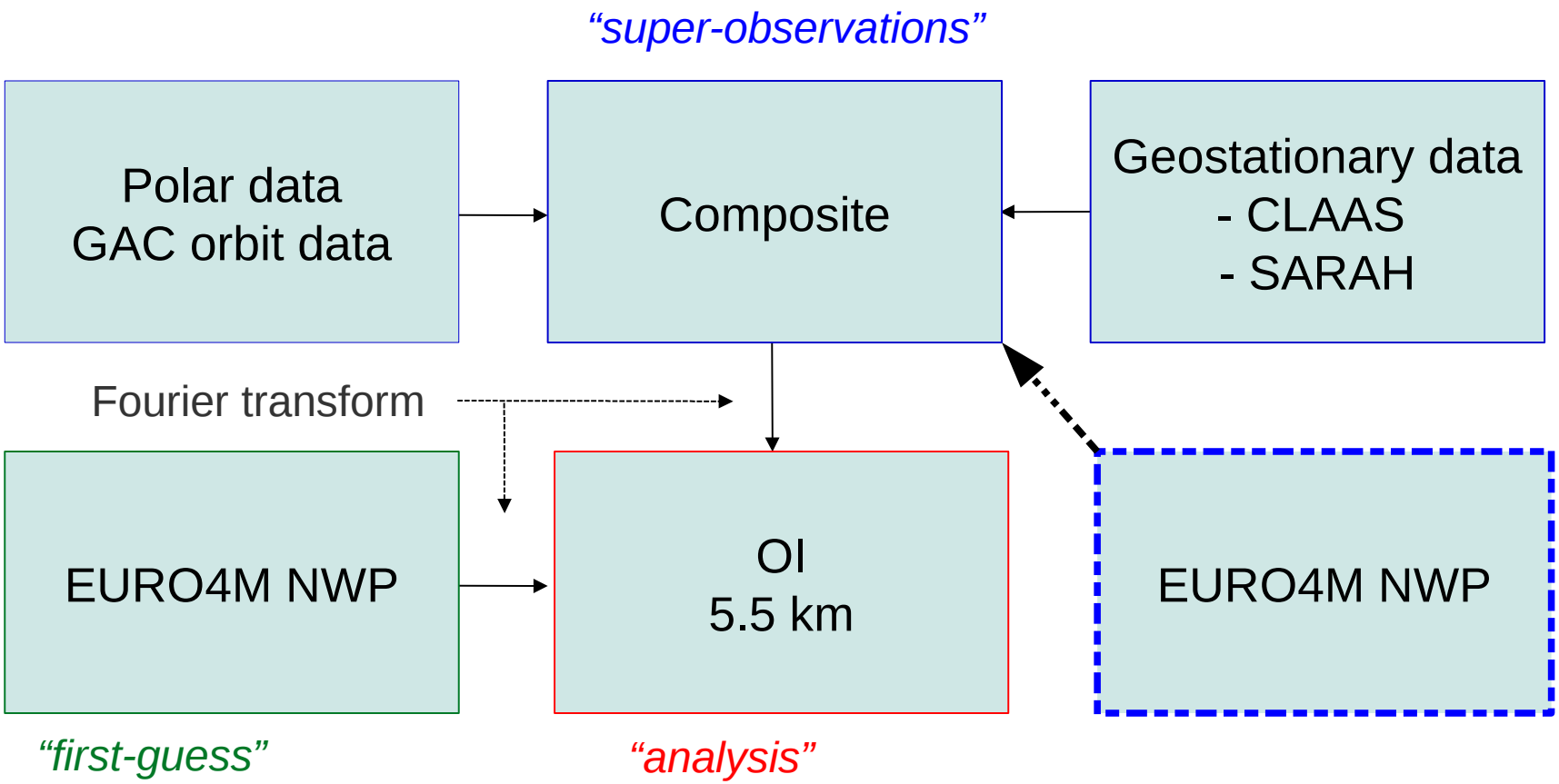
Processing chain



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Data overview

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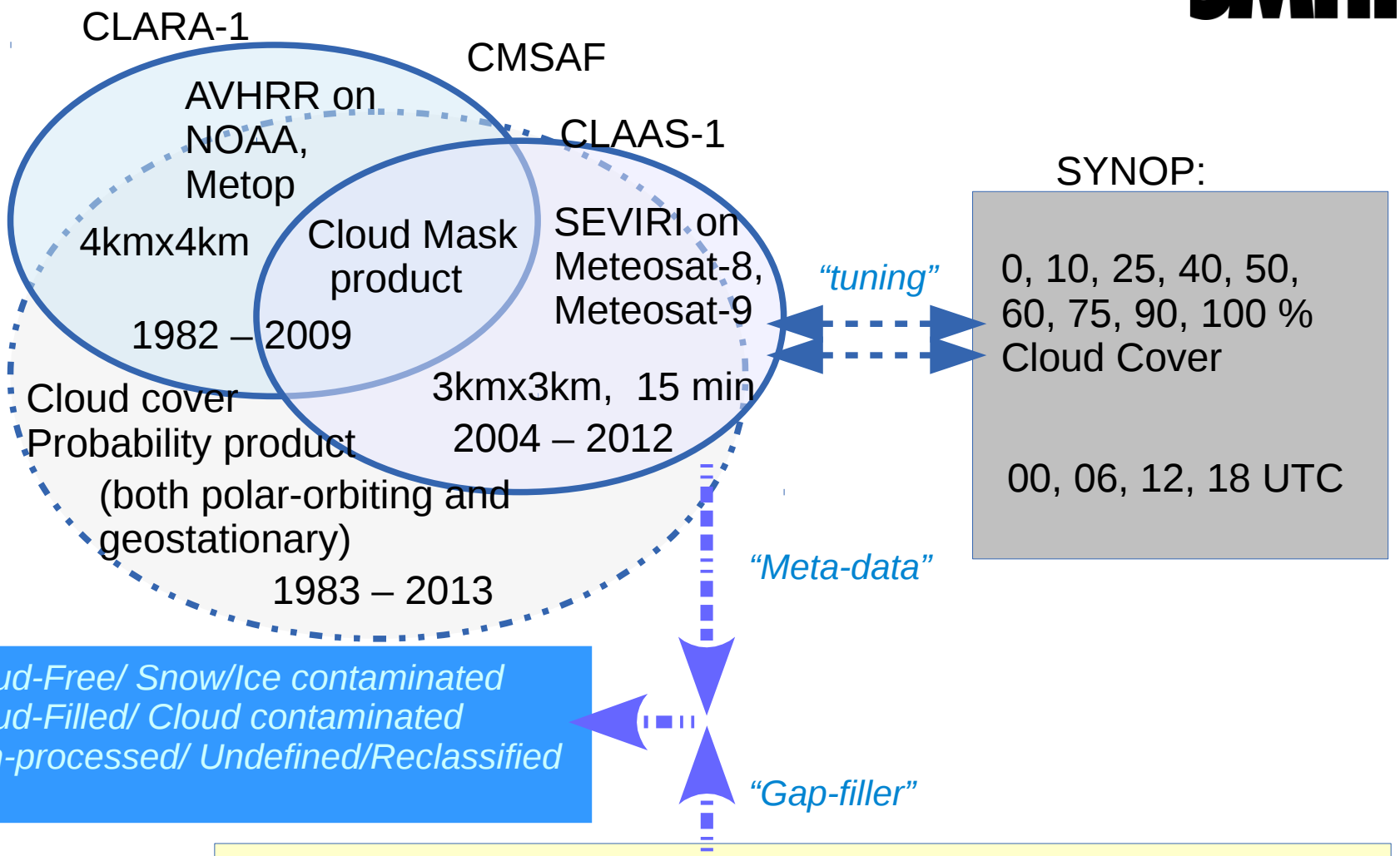

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Data resolution

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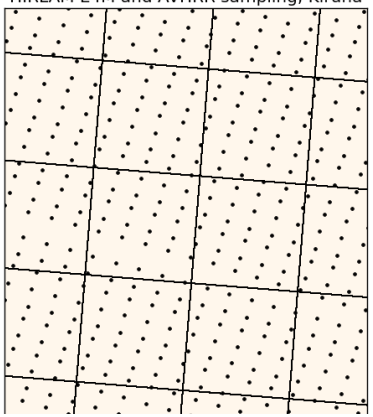
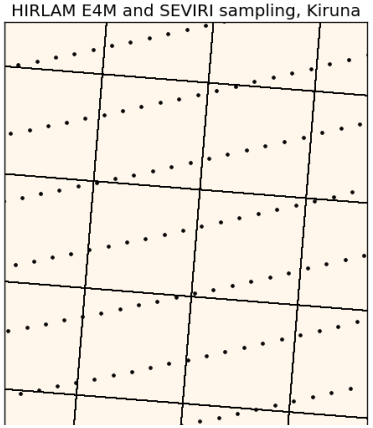
North

South

HIRLAM E4M and AVHRR sampling, Kiruna

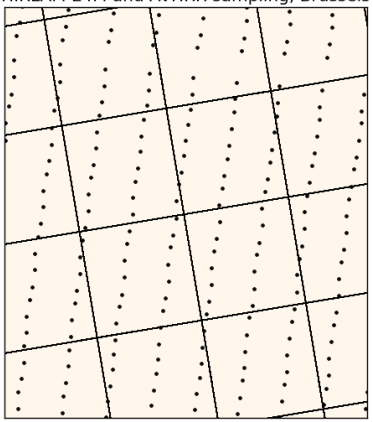


HIRLAM E4M and SEVIRI sampling, Kiruna

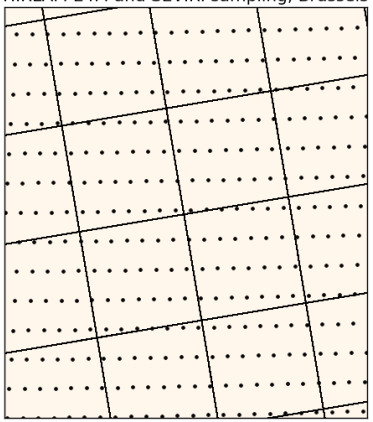


Kiruna
(67º51'21"N;
20º13'31"E)

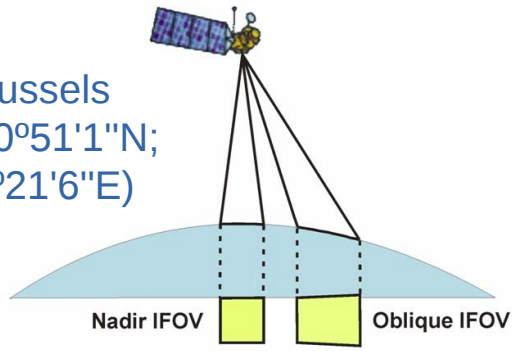
HIRLAM E4M and AVHRR sampling, Brussels

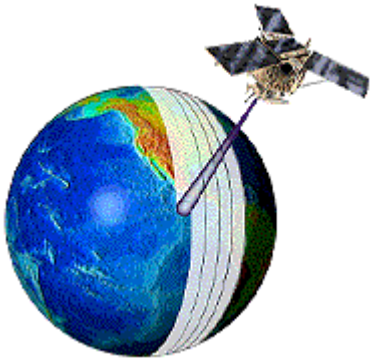


HIRLAM E4M and SEVIRI sampling, Brussels



Brussels
(50º51'1"N;
4º21'6"E)

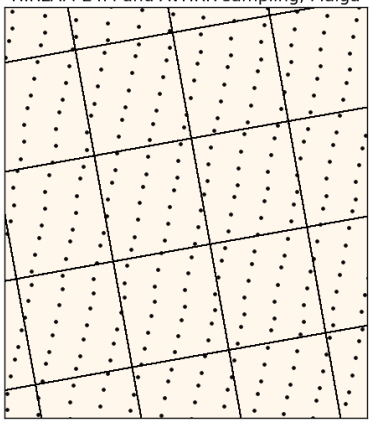




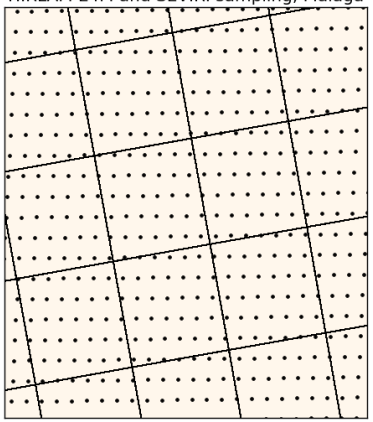
Polar -orbiting

Geostationary

HIRLAM E4M and AVHRR sampling, Malga



HIRLAM E4M and SEVIRI sampling, Malaga



Malaga
(36º43'17"N;
4º25'16"W)

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Quality Flags and Meta-Data

Bit number	Flag name	Description
0	Land	Pixel is over land.
1	Coast	Pixel is located in the coastal region.
2	Night	It is night where the pixel is located.
3	Twilight	The pixel is located in the twilight zone.
4	Sunglint	Sunglint is likely.
5	High terrain	Pixel is located over high terrain.
6	Inversion	Low level inversion is present according to NWP.
7	NWP present	NWP information have been used.
8	AVHRR channel missing	Some AVHRR channel is missing.
9	Low quality	One or more of the features of the decisive tests were close to one of its thresholds indicating low quality.
10	Reclassification	Pixel was re-classified in the filtering of isolated pixels.
11	Contaminated	The state before spatial smoothing (the filtering above) was cloud contaminated.
12	Cloudy	The pixel was cloudy before spatial smoothing.
13	External sea ice information	External sea-ice information used.
14	Internal sea ice information	Ice information derived from NWP.
15	Sea Ice	Sea-ice present according to sea ice maps.

Table 1: Description of the bits in the PPS processing flag.

Super observations

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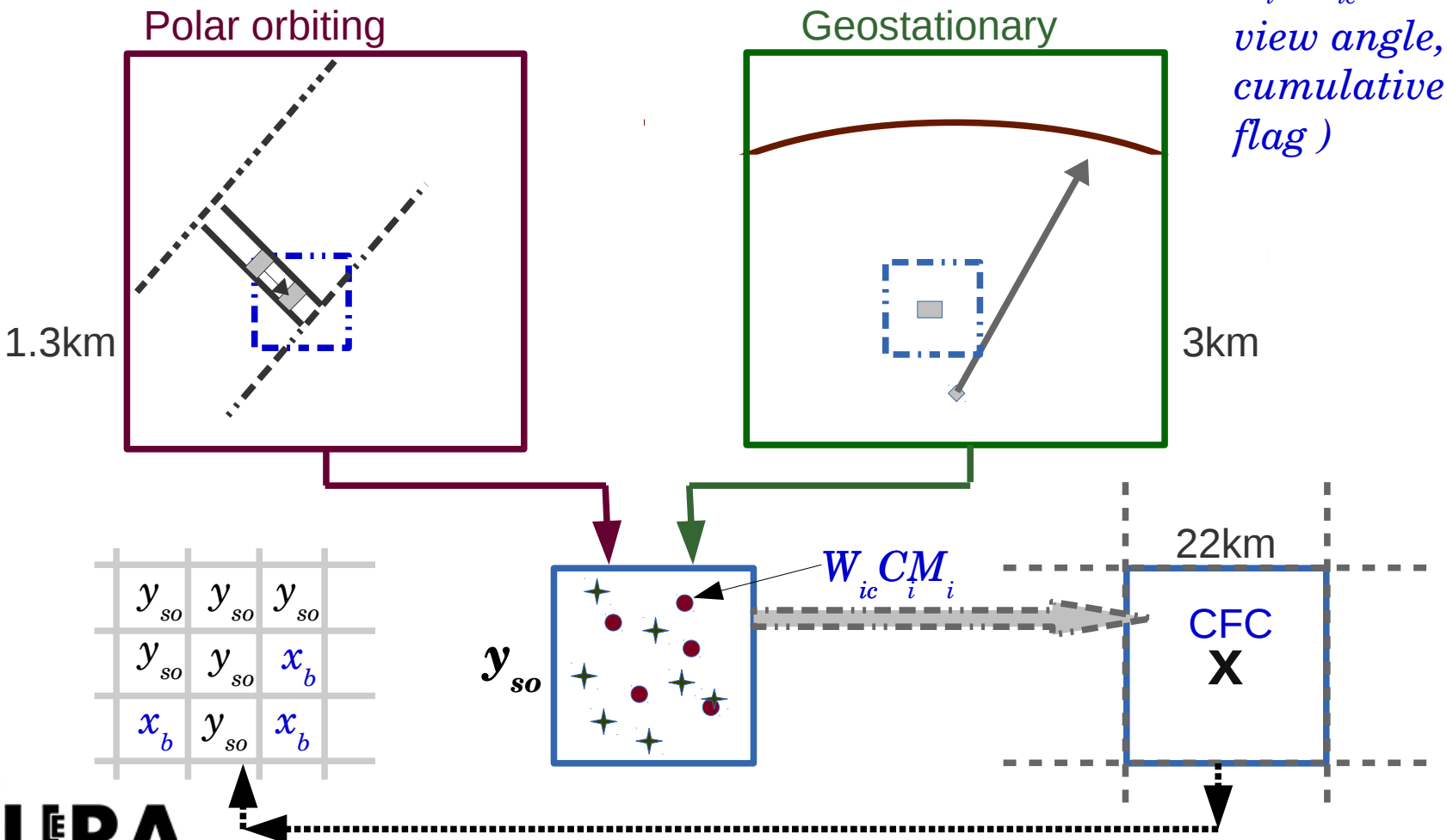
$$CFC = \frac{\sum w_i \, CM_i}{\sum w_i}$$

$w_i = W_{ic}$ (*timeliness, view angle, cumulative quality flag*)



HIRLAM EURO4M Cloud Fraction is used as “gap-filler” in grids where no CM observations available

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Super-observations (weighting)

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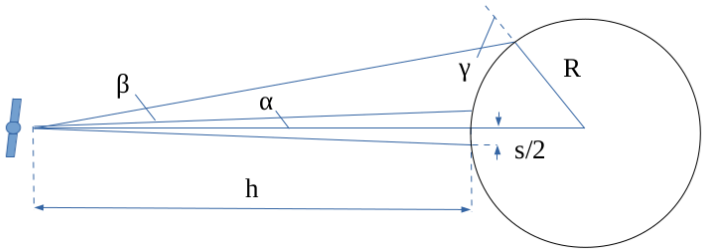
"timeliness"

$$w_{tdiff} = 1/2 + 1/2 \tanh(7 - \delta t \cdot 0.3)$$



"viewing angle/geometry"

$$\begin{aligned} \alpha &= 2\,atan(s/2/h) \\ w_{scan} &= h(\tan(\beta) - \tan(\beta - \alpha)) \\ w_{dist} &= 1 + \frac{R}{h}(1 - \cos(\gamma)) \\ w_{incl} &= 1/\cos(\gamma) \\ w_{geom} &= s/(w_{scan} w_{dist} w_{incl}) \end{aligned}$$

"quality control"

$w_{qc} = ½$: *sunlight/inversion/low, poor quality/sea-ice;*

$w_{qc} = 0$: *non-processed/ undifined/ reclassified*

$$w_i = w_{tdiff}\, w_{geom}\, w_{qc}$$

A median filter (7x7) is applied along the boarder of the missing data and in the areas of data with low quality ($\sum w_i < 0.75$; # pixels < 40)

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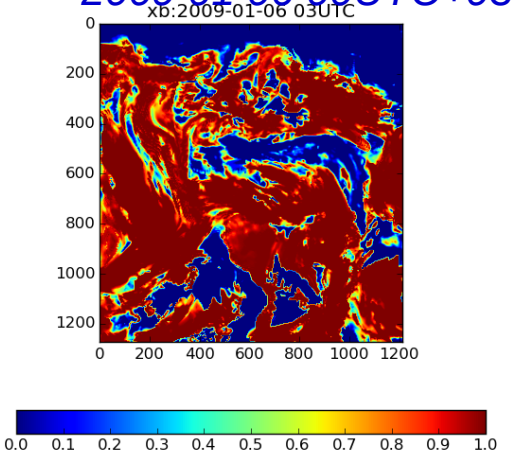
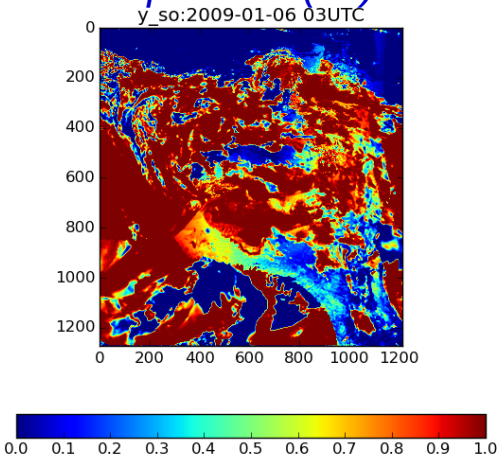
2009 01 06 03 UTC

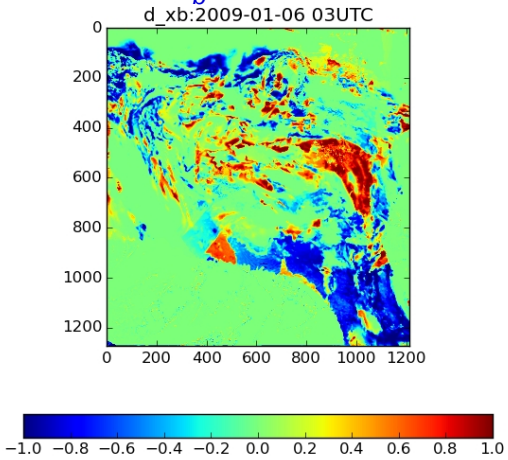
first-guess (fg)
2009 01 06 00UTC+03

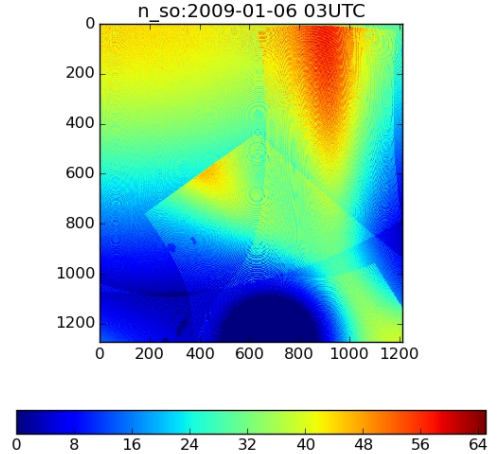


super-obs (so)

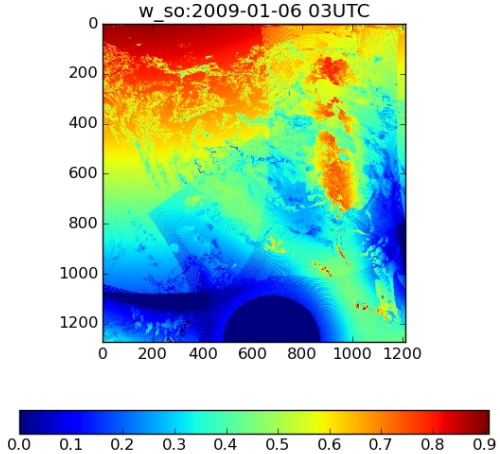


d^{so}_{b} *=so-fg*

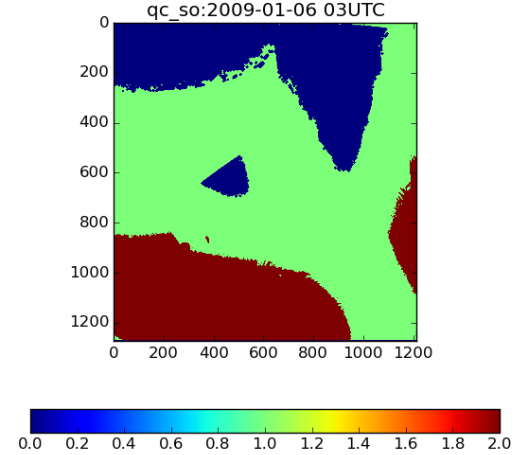




#pixels per so



mean w_i



quality indicator
0 – so
1 – mf (so&fg)
2 – fg

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Uncertainties in Ensembles of Regional ReAnalyses

Data coverage (2004-2009)

monthly mean

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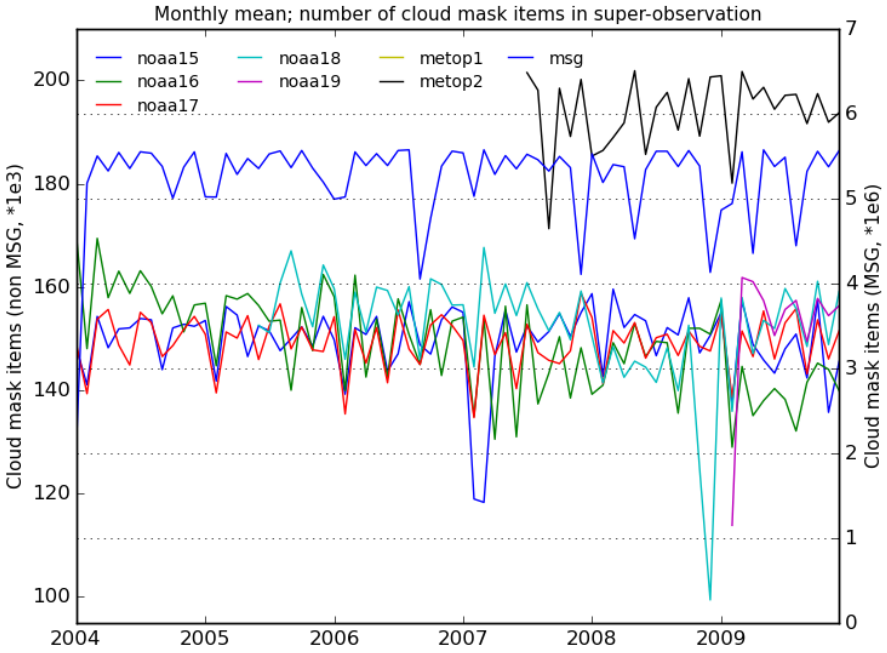
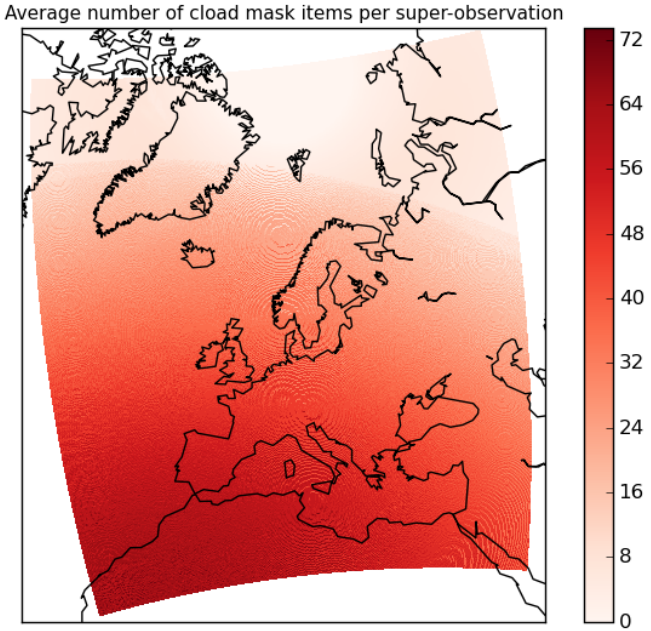


Non-MSG
$*10^3$

per satellite

MSG
$*10^6$



per gridbox
(average 2004-2009)

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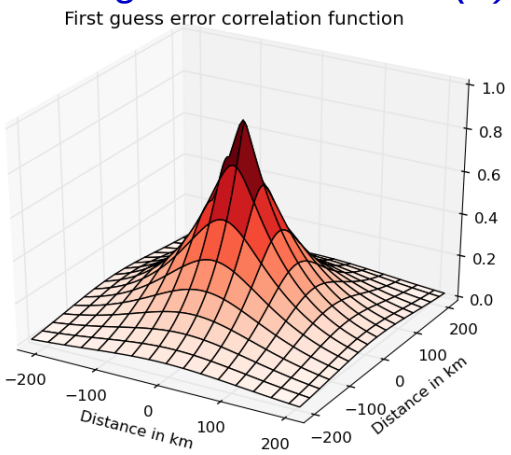
Optimum interpolation

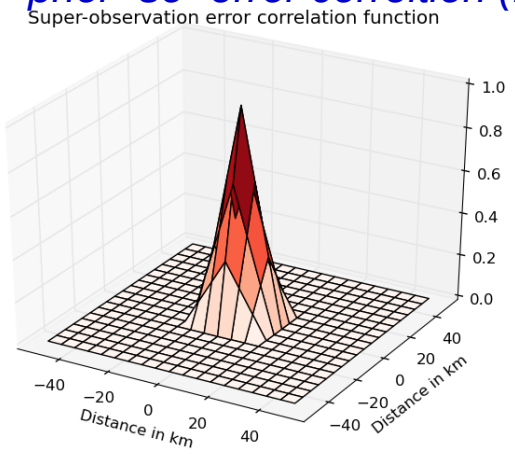
$$K_\nu = B_\nu (B_\nu + R_\nu)^{-1}$$
$$X^a_\nu = X^b_\nu + K_\nu (y_\nu - X^b_\nu)$$

analysis in Fourier space

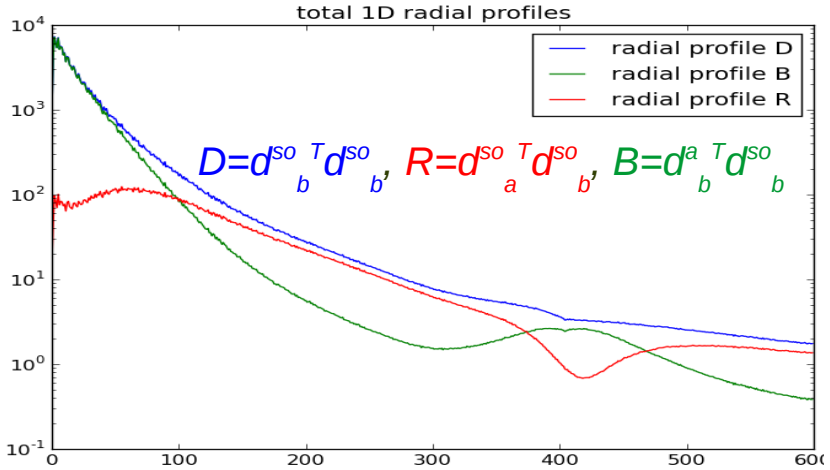
prior "fg" error correltion (B)



prior "so" error correltion (B)

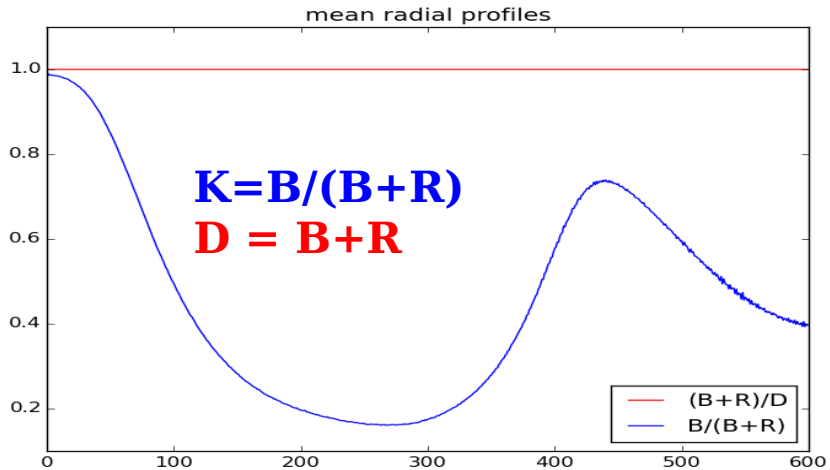


Posterior (Dezroziers) diagnostics



$D=d^{so}_b{}^T d^{so}_b$, $R=d^{so}_a{}^T d^{so}_b$, $B=d^{a}_b{}^T d^{so}_b$

Total 1D radial profile **(B,R,D)**



K=B/(B+R)
D = B+R

Mean Kalman Gain in spectral space

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2009 01 06 03 UTC

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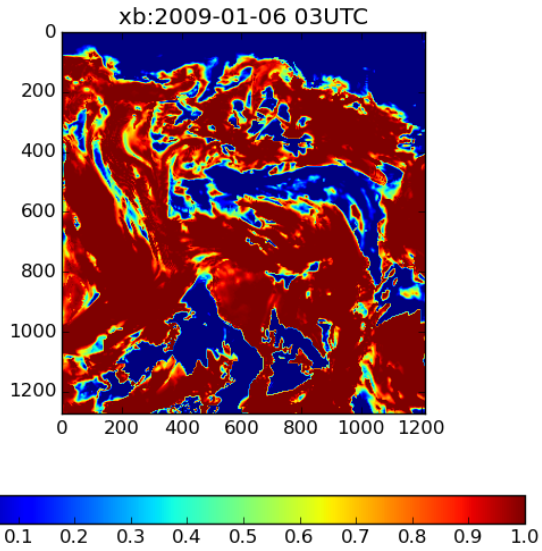
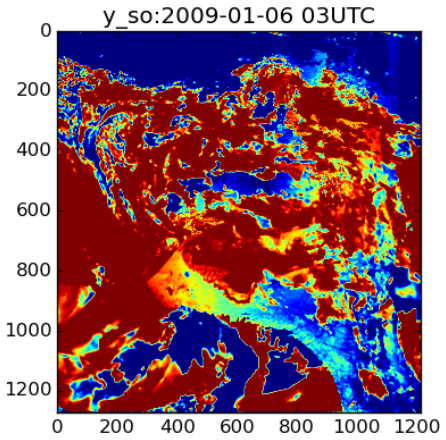
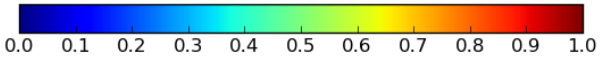
first-guess



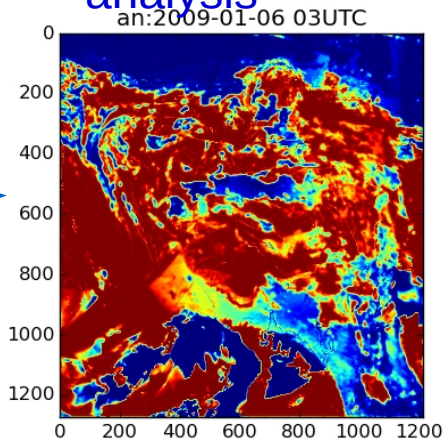
Optimal Interpolation

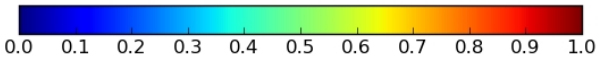
"super"-obs

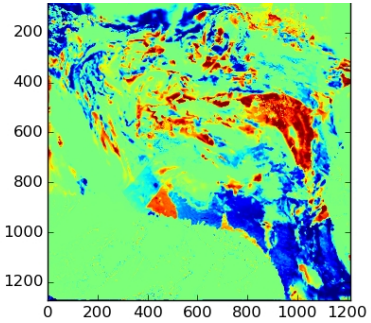


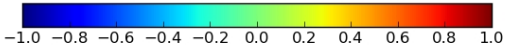


analysis

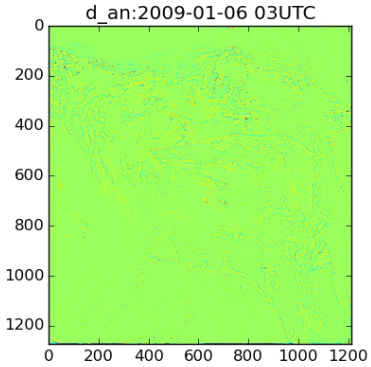


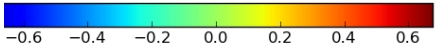






so-fg





so-an

of Regional ReAnalyses

Limitations of the optimal interpolation:

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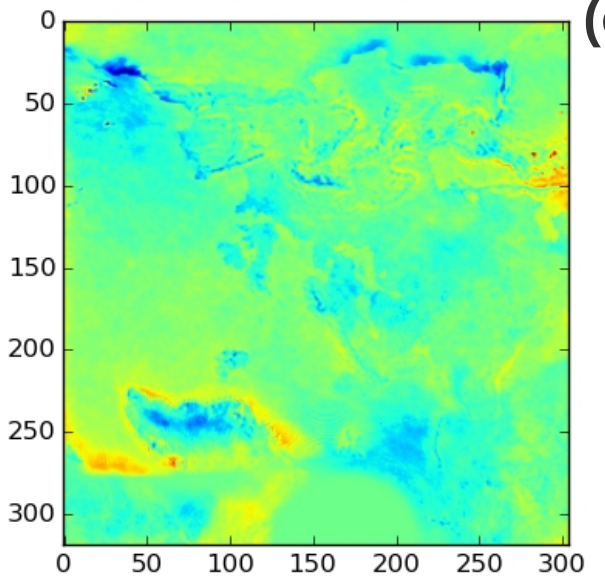
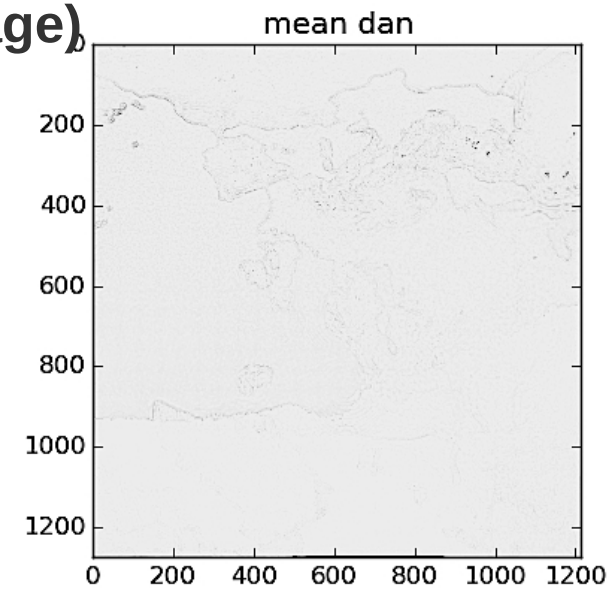
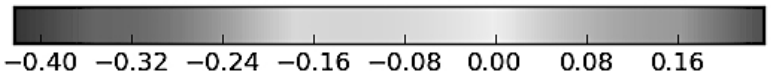
Total cloud cover (03 UTC 2009)
(one year average)



“Obs-minus-Forecast”
– innovations





“Obs-minus-Analysis”
– residuals

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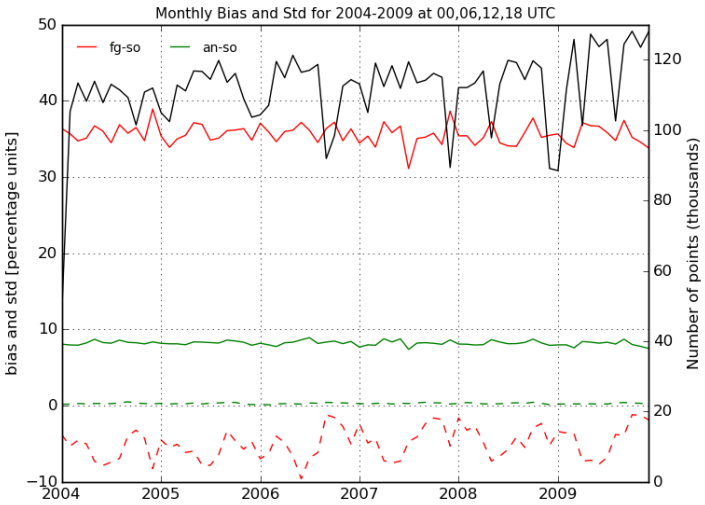
Verification (against observations)

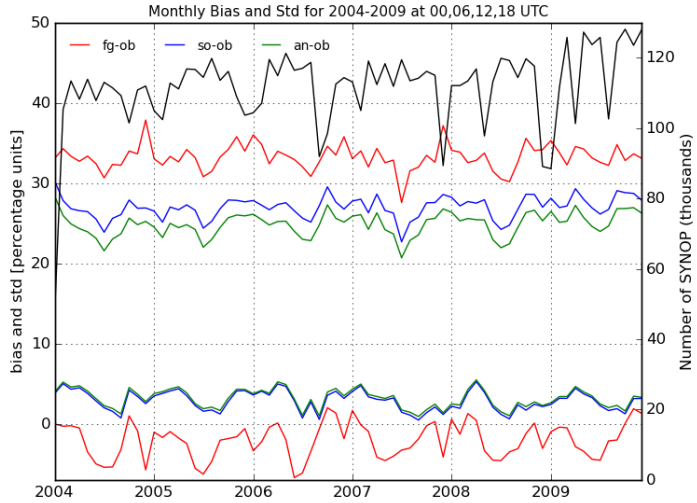
Monthly bias/std



against own data

+ Analysis has lower std than both the first-guess and super-observations.

– On average the analysis has too much clouds against SYNOP



against SYNOP

Scale-dependent decomposition
(similarity analysis)

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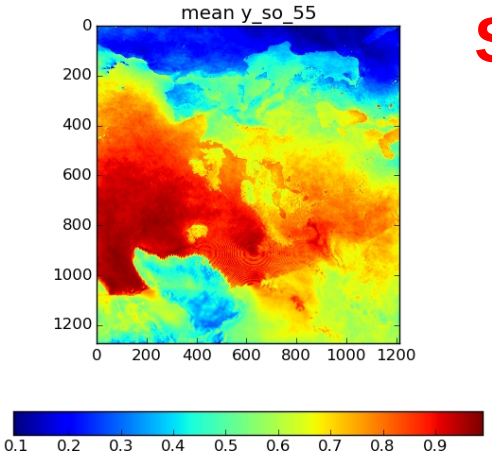
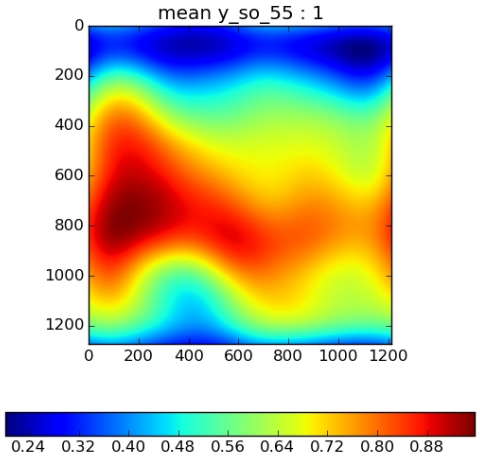
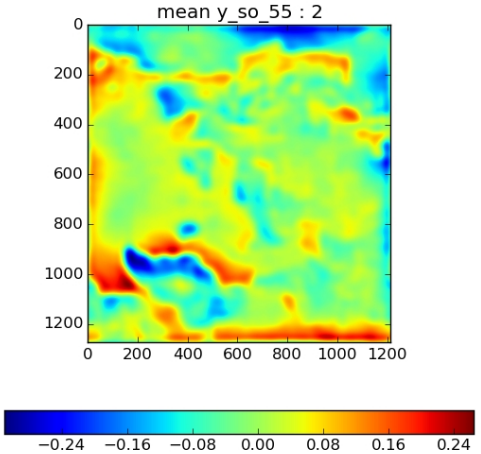


Scale 1



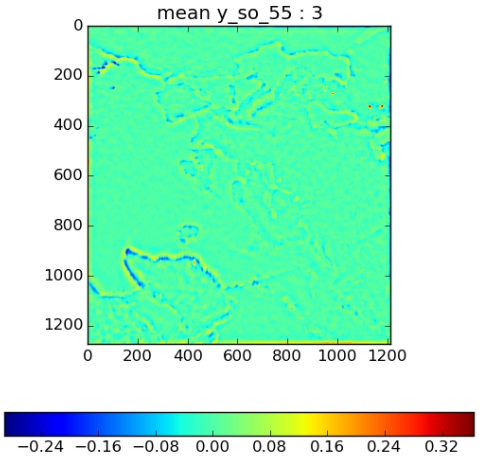
Scale 2



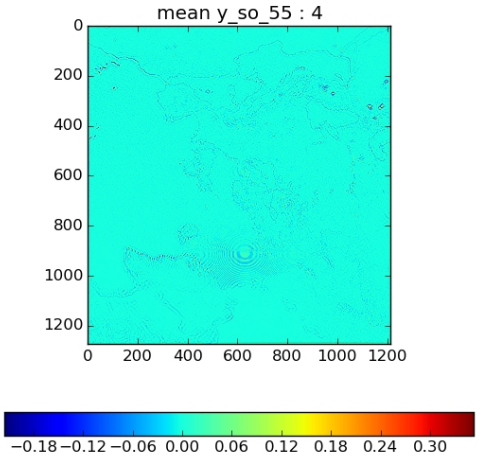
One-year Average
(5.5km resolution)

2009 03 UTC

Scale 3



Scale 4



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Scale-dependent decomposition

(high-frequencies)

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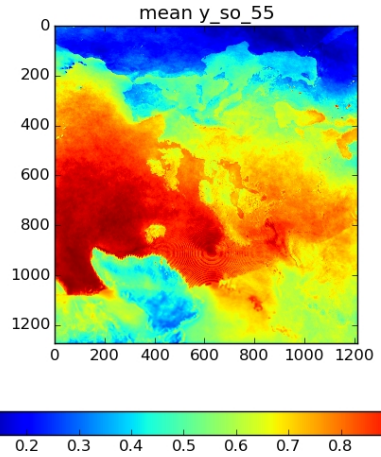
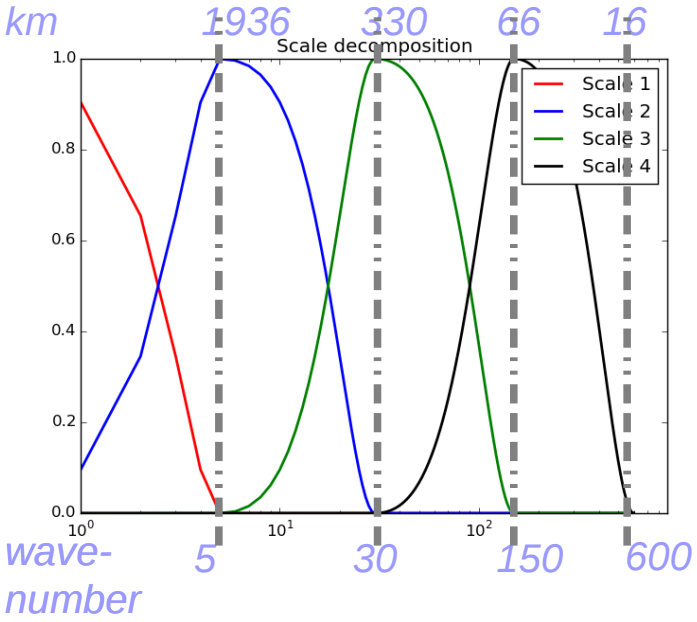
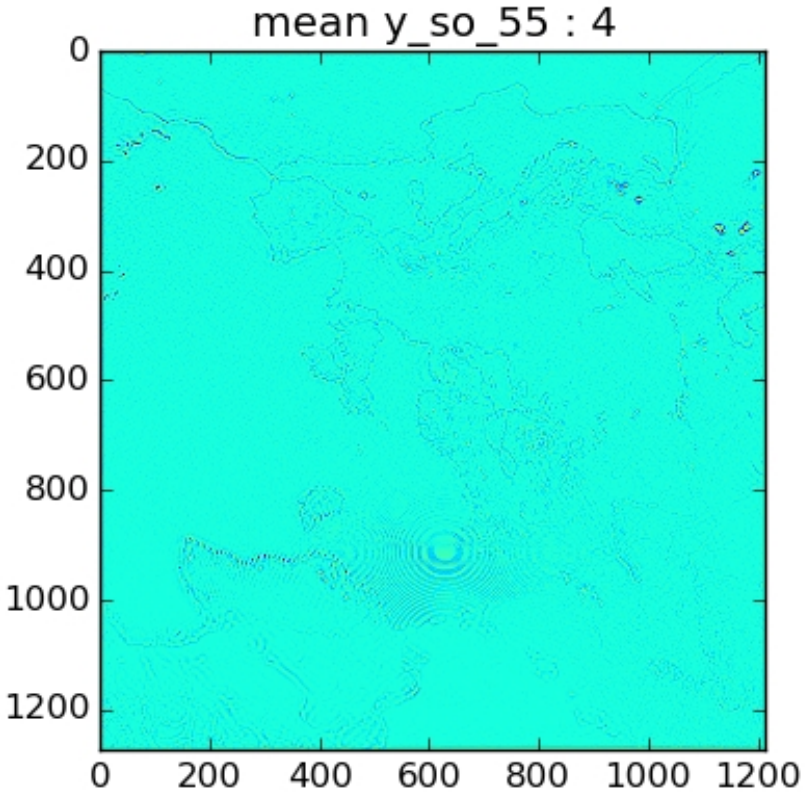
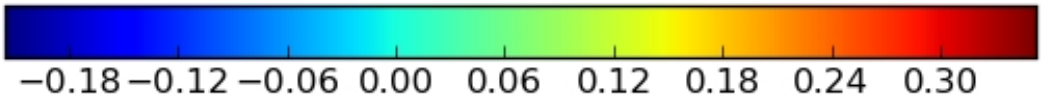




Scale 4





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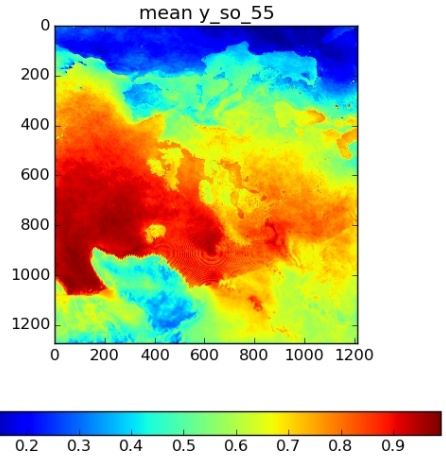
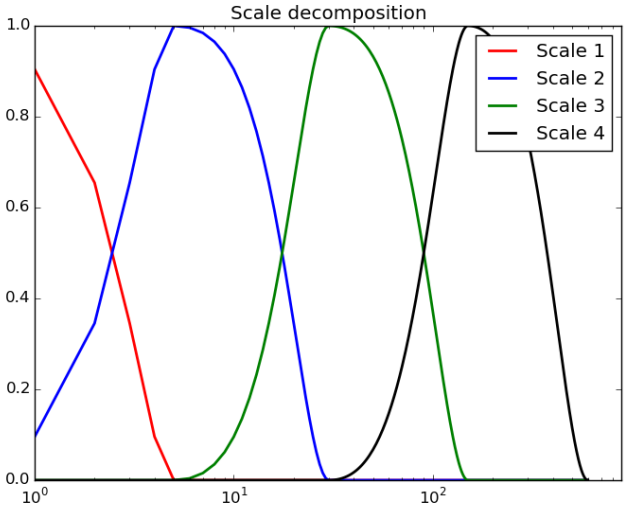
Uncertainties in Ensembles of Regional ReAnalyses

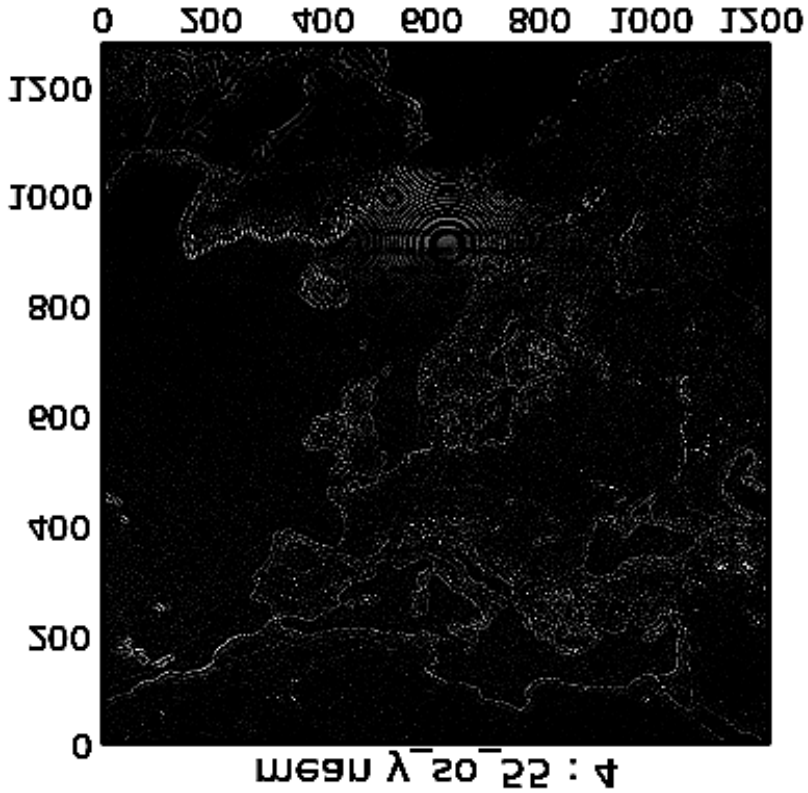
Super-observations contain realistic information on frequencies higher than those resolved by first-guess field



Upside-down?

SMHI





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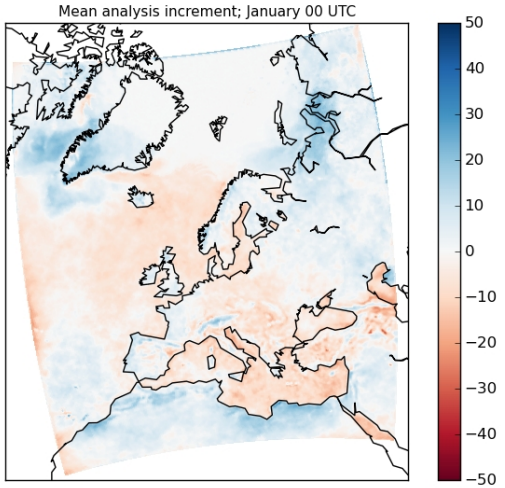
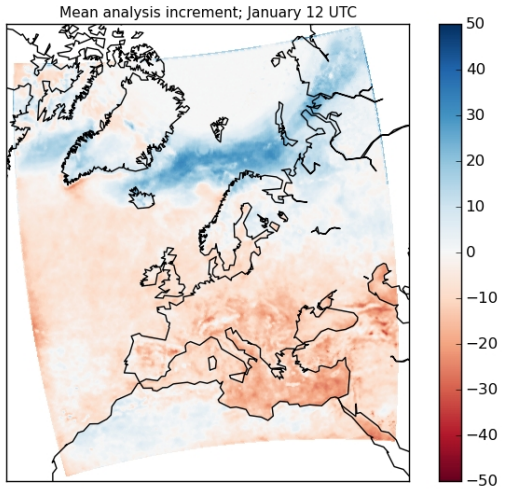
Analysis increment (*100)

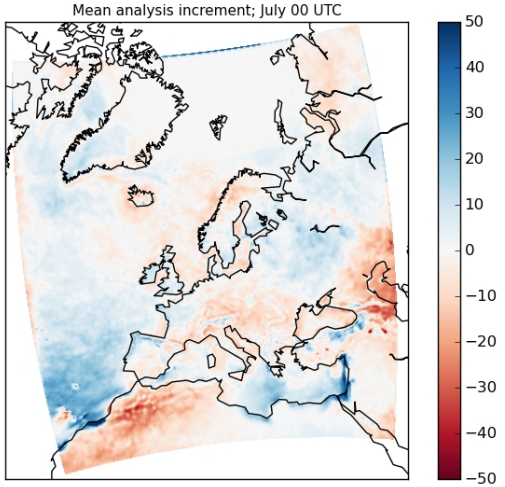
climatology



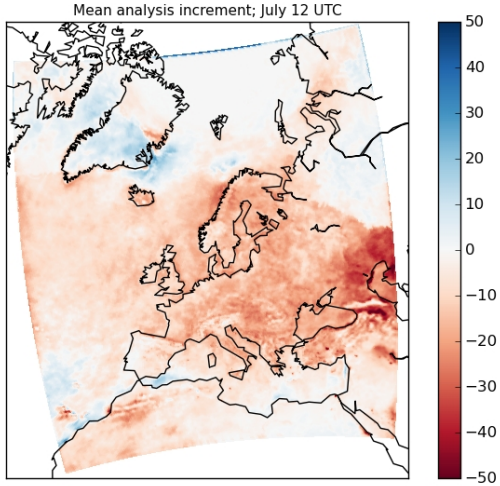
January 00UTC



January 12UTC



July 00UTC



July 12UTC

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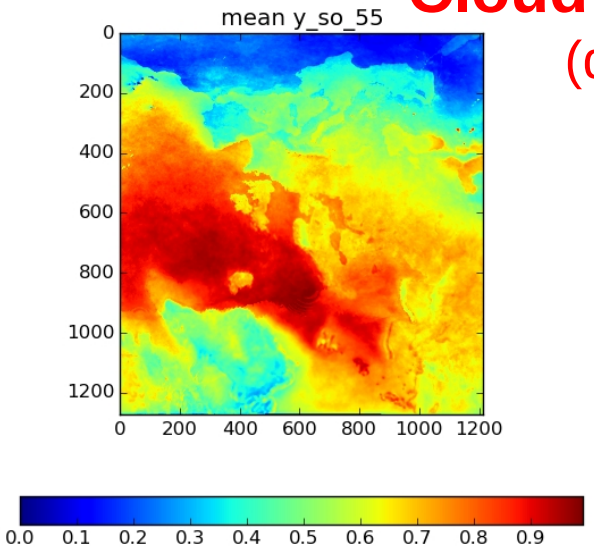
Cloud Cover Analysis

(daily cycle)



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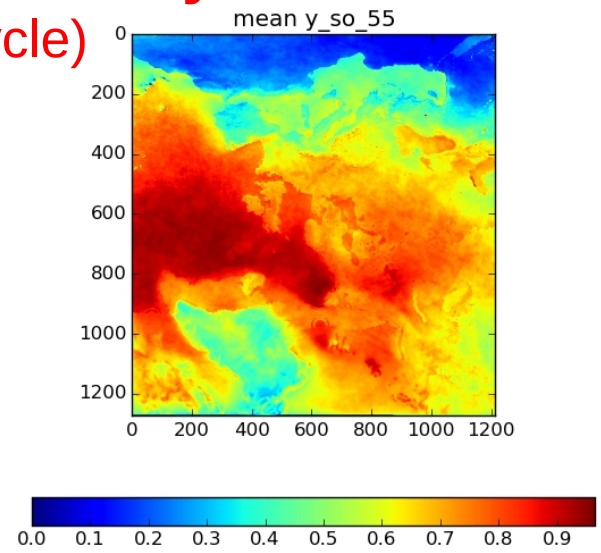

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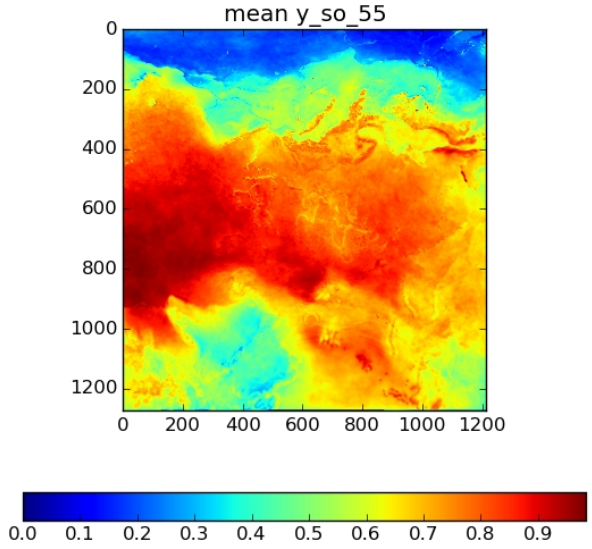

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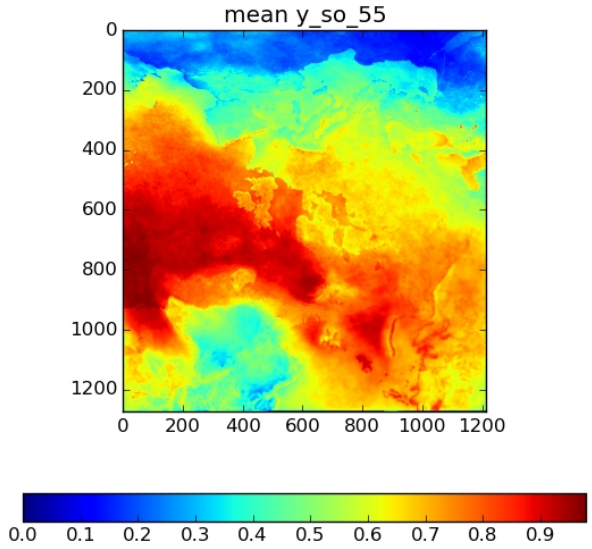

18UTC

of Regional ReAnalyses

Summary

SMHI

Done!

✔ An hourly analysis of total cloud cover on a grid with horizontal resolution 5.5km has been produced for 2004-2009 as Deliverable D2.6 to UERRA project.

✔ Optimum interpolation scheme was used to merge together EURO4M Cloud Fraction Reanalysis and Super-Observations, that are the weighted averages of binary cloud mask data from CM SAF CLAAS-1 and CLARA-A1 datasets over a neighborhood

✔ The analysis produces realistic cloud cover fields that verify well against independent data, including SYNOP observation

More work/attention is needed!

➔ Super-observations has a positive bias → Why? More investigations are need.

➔ Super-observations introduce moire pattern → Currently a median filter is applied to reduce the impact from it. The methodology should be revisited and improved.

➔ Estimation of background and observation error statistics by different methods were not fully consistent → The reason needs to be understood.

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And then!!!

CLARA-A2 (1982-2014) + cloud cover probability product (1983-2015) + EURO4M Cloud Fraction => 30 years of Cloud Cover Analysis!