Hourly precipitation analysis combining rain-gauge observations with radar estimates

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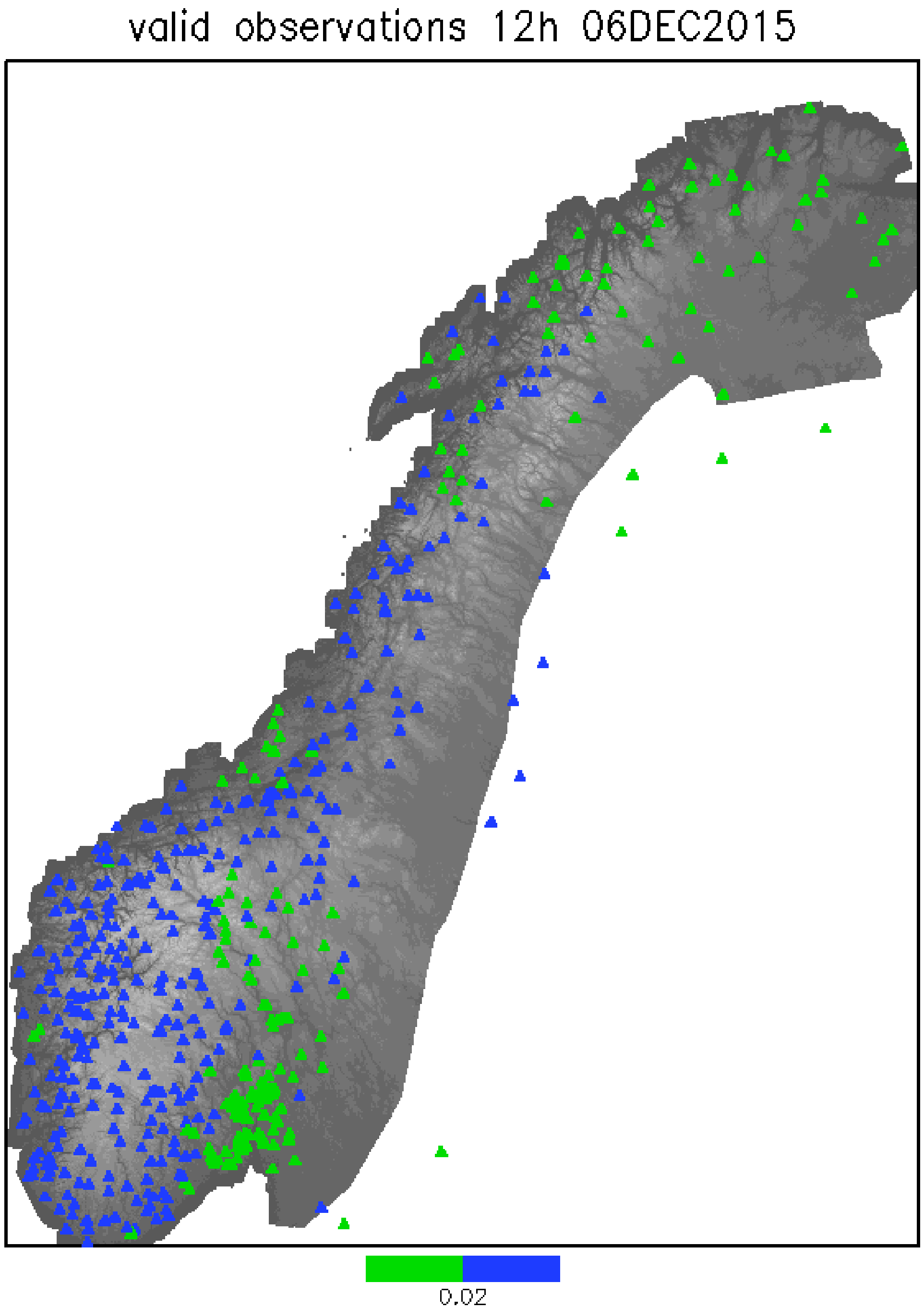
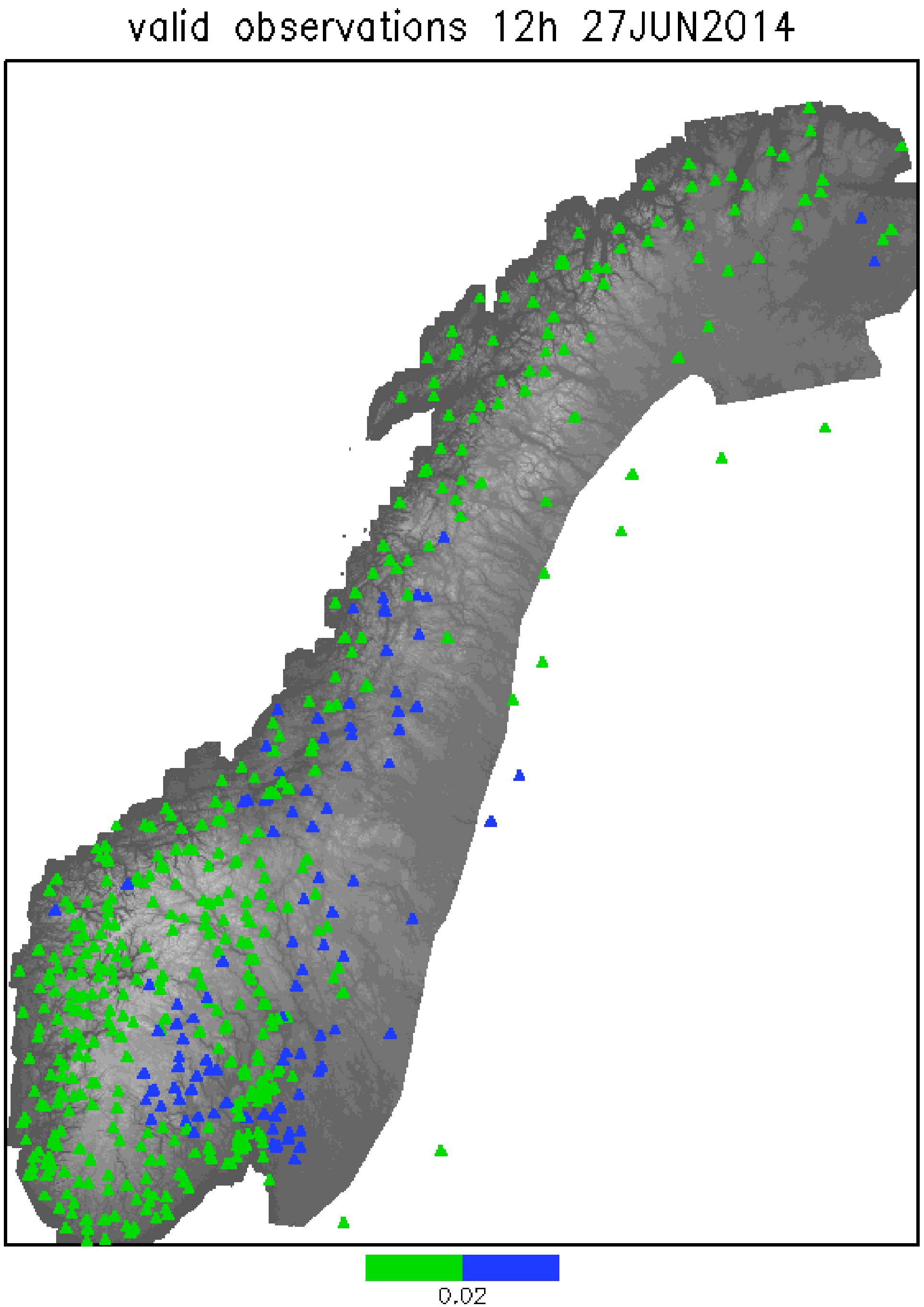
Precipitation analysis combining rain-gauge observations with radar estimates

Buliding blocks

- Rain-gauge observations: $\mathbf{y}^o$
- Background field ← radar estimates: $\mathbf{x}^b$ on gridpoints, $\mathbf{y}^b$ on station points
- Innovation: $\mathbf{y}^o$ - $\mathbf{y}^b$

Precipitation analysis combining rain-gauge observations with radar estimates





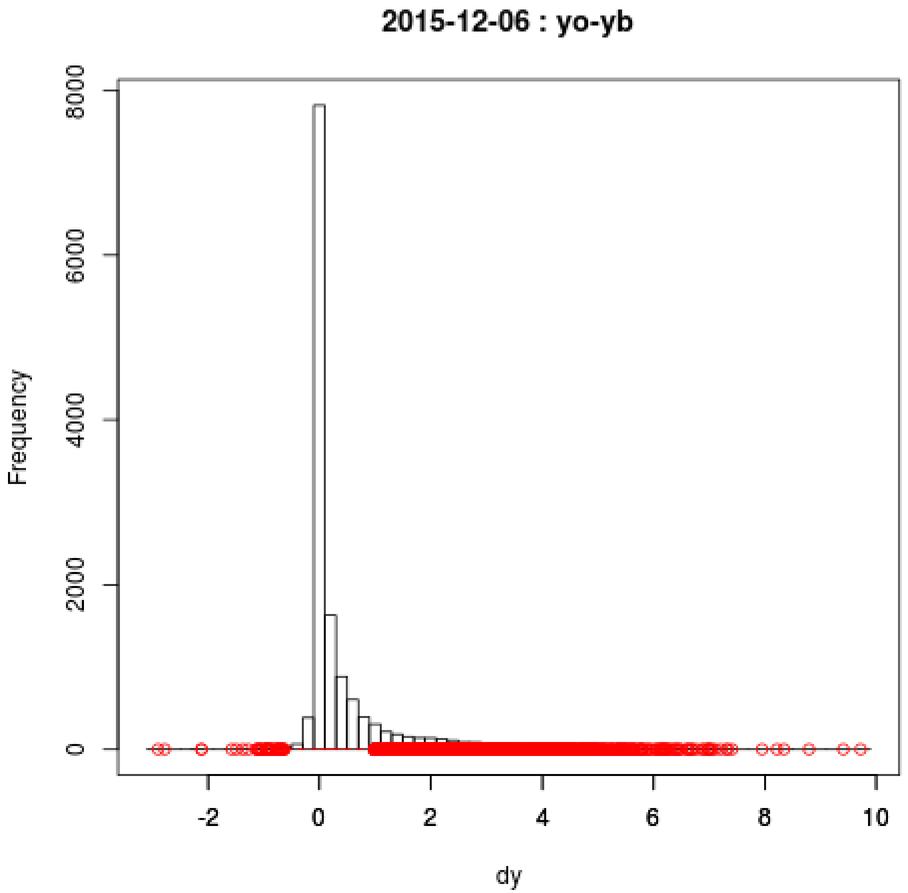
Precipitation analysis combining rain-gauge observations with radar estimates

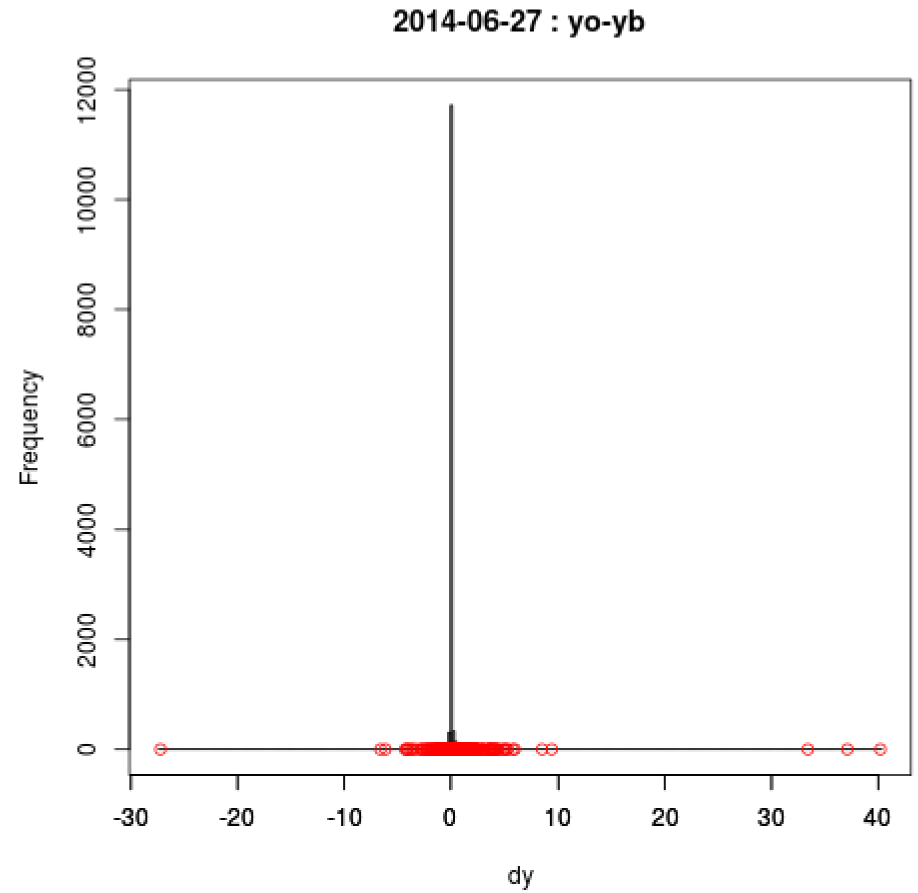
Precipitation analysis combining rain-gauge observations with radar estimates

Preliminary choice

- Use the same interpolation parameters in convective and stratiform precipitation events
- Compromise
- Questionable...
- Otherwise 1: change parameters with season or month?
- Otherwise 2: Detect proportion convective /stratiform: how?
  - Use model forecasts?
  - Analysis of radar estimation “fields”?
- Not for the moment

Precipitation analysis combining rain-gauge observations with radar estimates





13946

12912

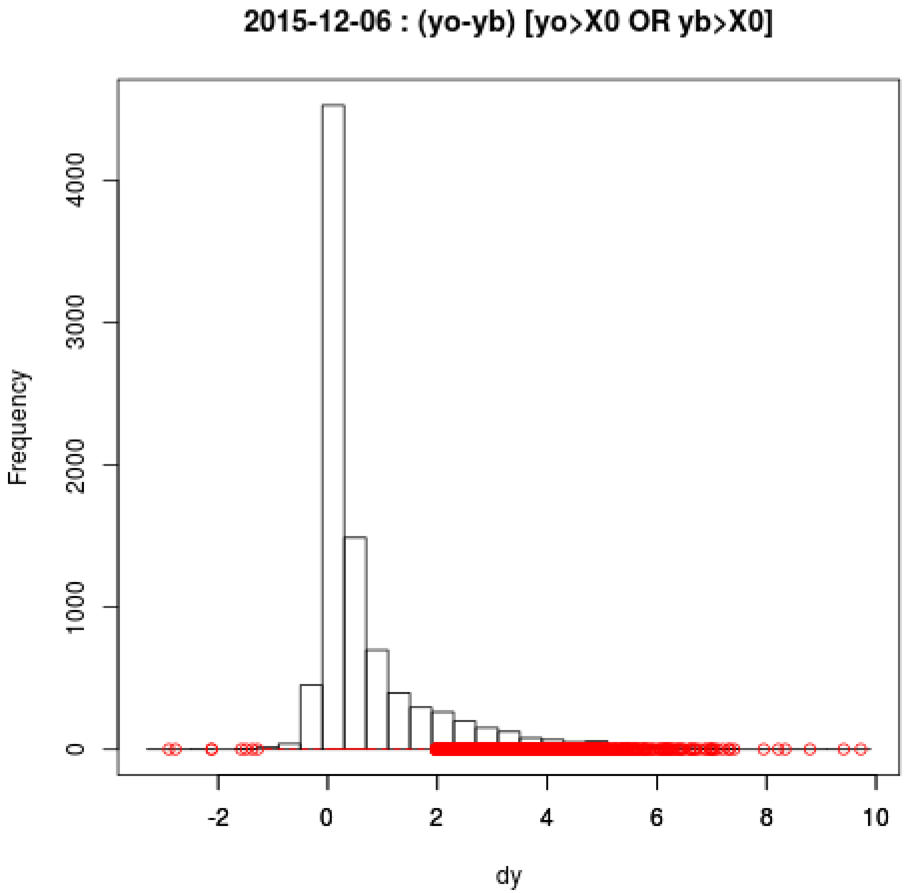
$dy = y^o - y^b$ (mm)

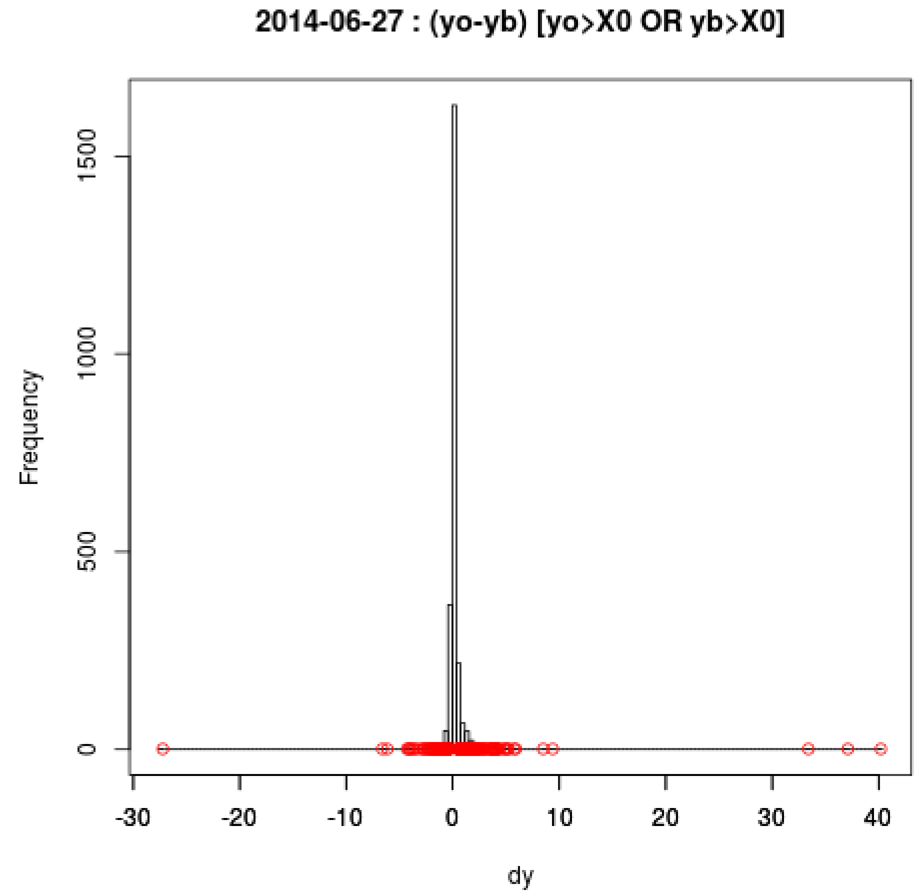
Precipitation analysis combining rain-gauge observations with radar estimates

Choices:

- Separate areas (gridpoints and station points) where precipitation is occurring from areas where there is no precipitation

Precipitation analysis combining rain-gauge observations with radar estimates





9024

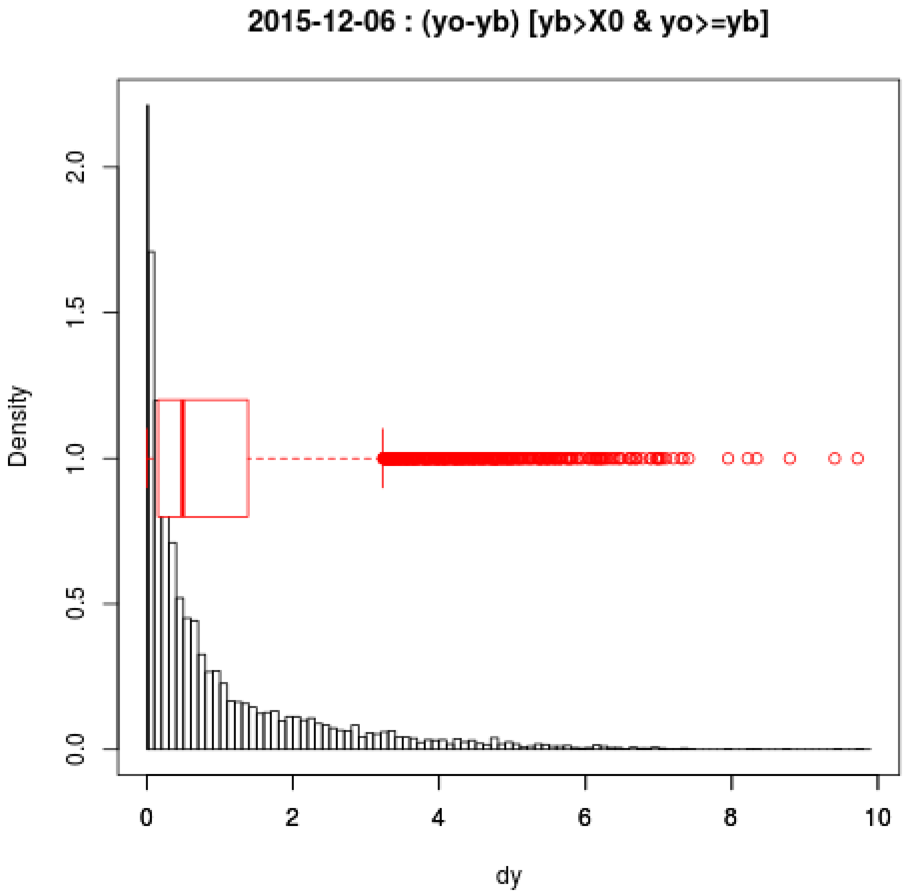
2496

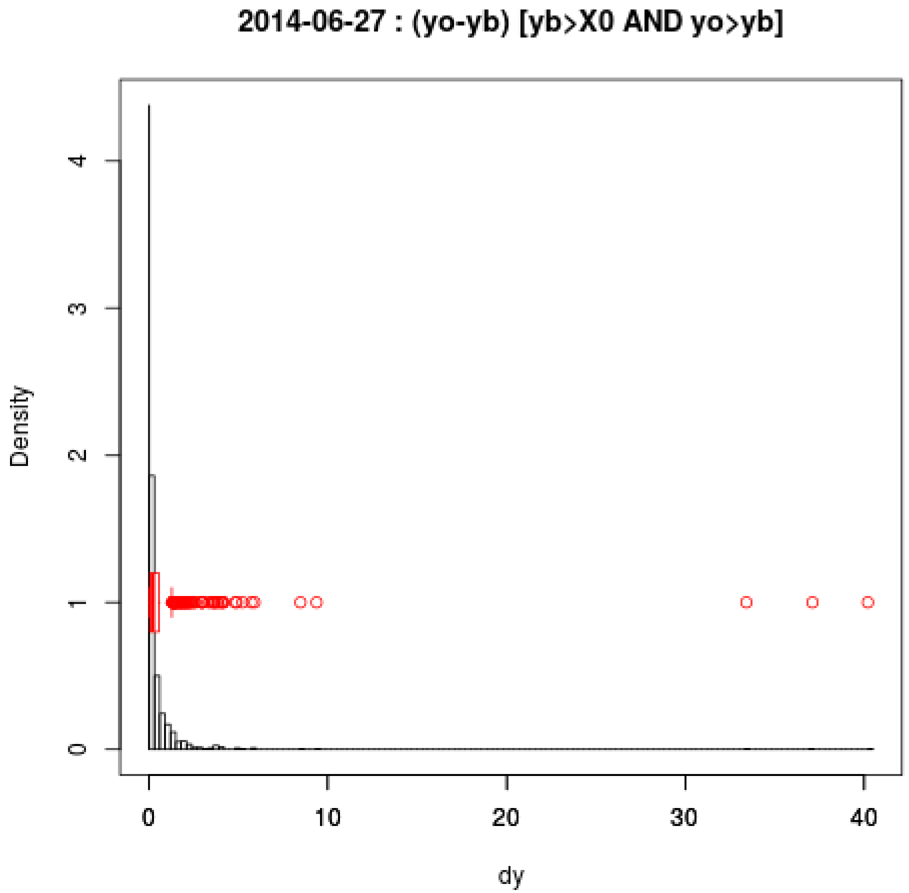
Precipitation analysis combining rain-gauge observations with radar estimates

Choices:

- Separate areas (gridpoints and station points) where precipitation is occurring from areas where there is no precipitation
- Where it rains, assume that it rains at least as much as the radar estimates: $\mathbf{x}^b$ on gridpoints, $\mathbf{y}^b$ on station points
  - Make use of rain-gauge measurements $\mathbf{y}^o$ only where they are larger than the corresponding radar estimate $\mathbf{y}^b$
  - Then innovation is positive: $\mathbf{y}^o - \mathbf{y}^b > 0$
  - A rain-gauge observation is considered *innovative* only when it exceeds the radar estimate used as background value.

Precipitation analysis combining rain-gauge observations with radar estimates

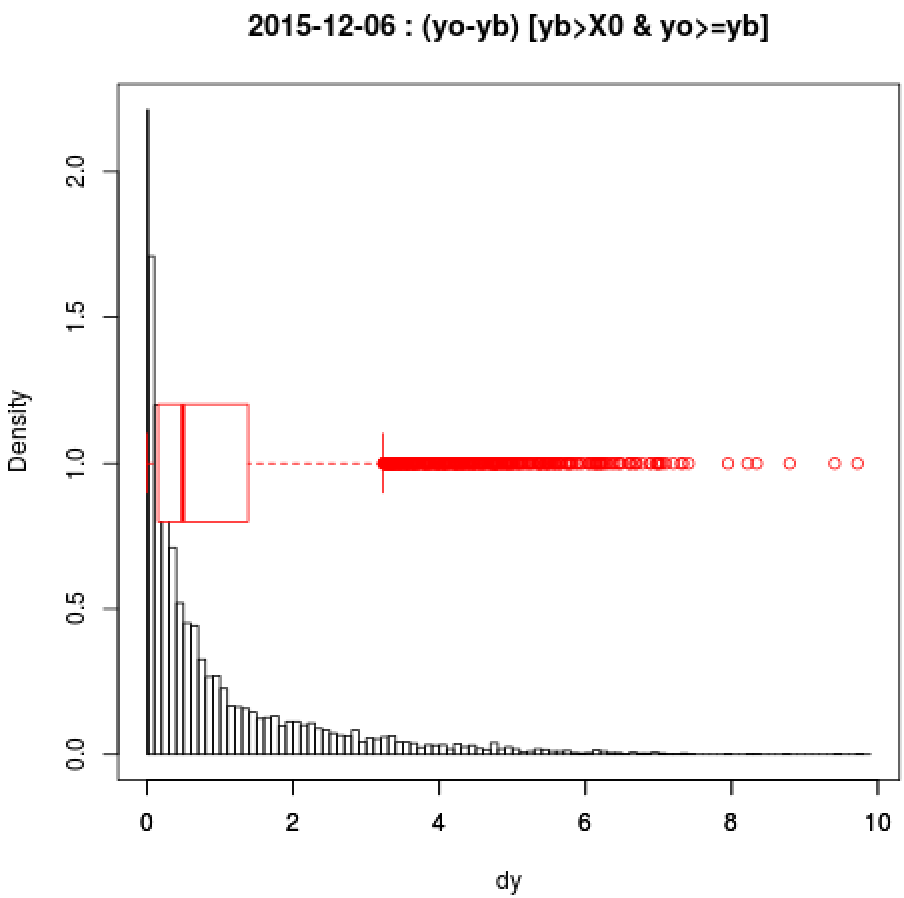


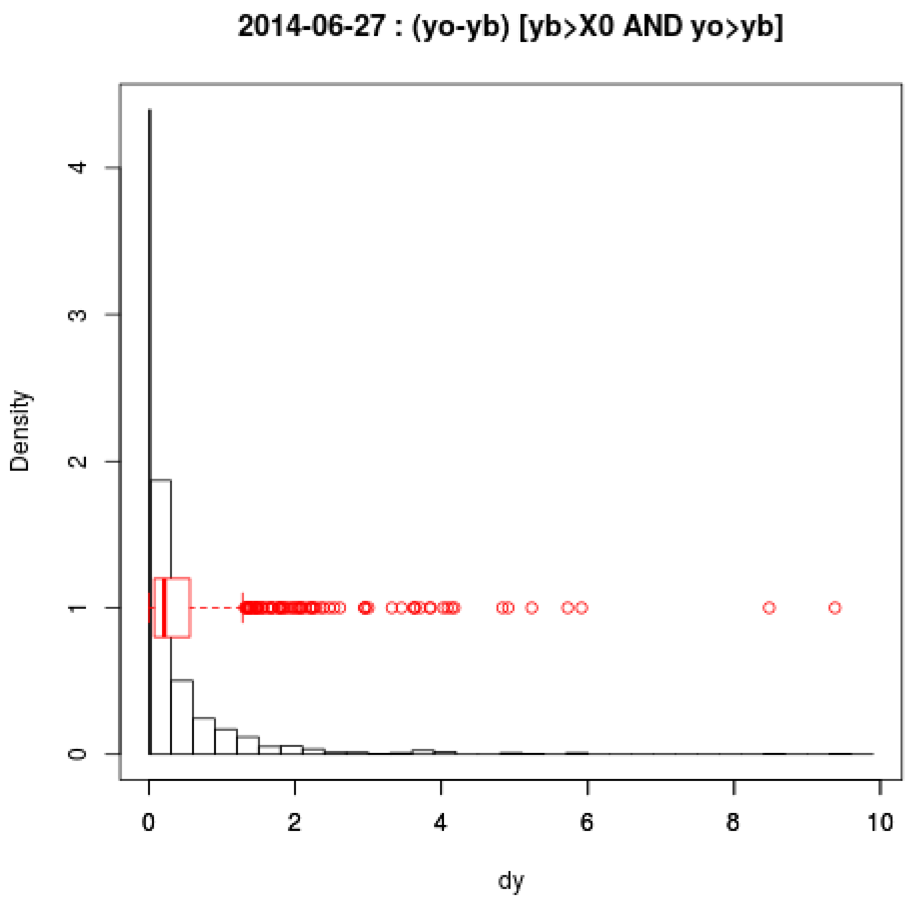


5514

765

Precipitation analysis combining rain-gauge observations with radar estimates





5514

Less than 10 mm: 762

Precipitation analysis combining rain-gauge observations with radar estimates

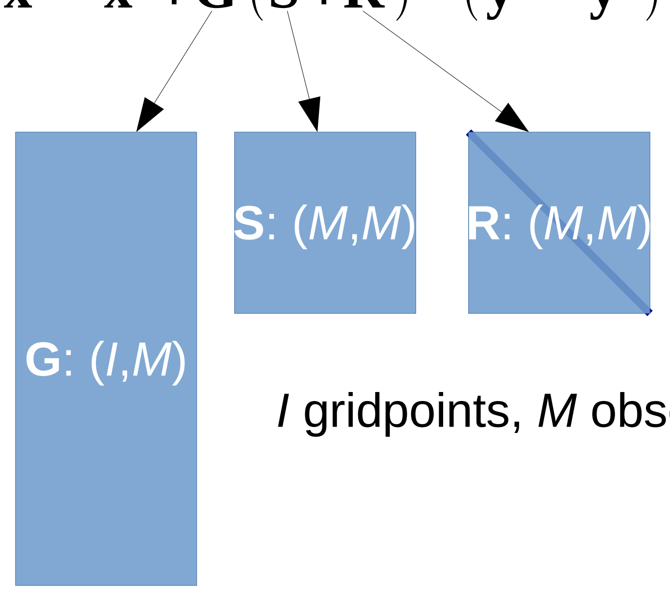
Choices:

- Separate areas (gridpoints and station points) where precipitation is occurring from areas where there is no precipitation
- Where it rains, assume that it rains at least as much as the radar estimates: $\mathbf{x}^b$ on gridpoints, $\mathbf{y}^b$ on station points
  - Make use of rain-gauge measurements $\mathbf{y}^o$ only where they are larger than the corresponding radar estimate $\mathbf{y}^b$
  - Then innovation is positive: $\mathbf{y}^o - \mathbf{y}^b > 0$
  - A rain-gauge observation is considered *innovative* only when it exceeds the radar estimate used as background value.
- Then, proceed with usual O. I. (Optimal interpolation)
  - Questionable: still non-gaussian (skewed: gamma?)
  - Small ratio $\sigma_o^2/\sigma_b^2 = 0.1$: give confidence to these observations.

Precipitation analysis combining rain-gauge observations with radar estimates

OI and covariances

$$\mathbf{x}^a = \mathbf{x}^b + \mathbf{G}\left(\mathbf{S}+\mathbf{R}\right)^{-1}\left(\mathbf{y}^o - \mathbf{y}^b\right)$$



$$\mathbf{R} = \sigma_o^2 \mathbf{I}$$

I gridpoints, *M* observations

G: (*I*,*M*) : background error covariance gridpoints – observation points
S: (*M*,*M*): background error covariance observation points – observation points
R: (*M*,*M*): observation error covariance (assumed diagonal)

Precipitation analysis combining rain-gauge observations with radar estimates

Background Correlation function(s)

$d_{i,m}$: distance between (grid/station) point *i* and station point *m*
c_i : radar attenuation class at (grid/station) point *i*
D_h : decorrelation distance

$$G_{i,m} \text{ or } S_{i,m} = \sigma_b^2 \left(1 + \frac{d_{i,m}}{D_h}\right) \exp\left(-\frac{d_{i,m}}{D_h}\right) \cdot \left[1 - \left(c_i - c_m\right)^2\right]$$

$$G_{i,m} \text{ or } S_{i,m} = \sigma_b^2 \exp\left[-\frac{1}{2}\left(\frac{d_{i,m}}{D_h}\right)^2\right]$$

G: (*I*,*M*) : background error covariance gridpoints – observation points
S: (*M*,*M*): background error covariance observation points – observation points
R: (*M*,*M*): observation error covariance (assumed diagonal) $\mathbf{R} = \sigma_o^2 \mathbf{I}$

D_h: tested various values, best results for D_h = 20 km;
$\sigma_o^2/\sigma_b^2 = 0.1$

Precipitation analysis combining rain-gauge observations with radar estimates

Separate areas: precipitation / no precipitation

Choices:

- Threshold $X_0 = 0.02$ mm
- "ZERO" obs: $0 < y^o < X_0$ → **IDI** (**I**ntegral **D**ata **I**nfluence, grid and station points): $\mathbf{IDI_Z}$
- "POSITIVE" obs: $\boldsymbol{y^o > X_0}$ **&** $\boldsymbol{y^o > y^b}$ **larger than** $\boldsymbol{X_0}$ **AND than background** → $\mathbf{IDI_P}$
- **IDI = Integral Data Influence:**

  analysis of all **"observations" = 1**, with **background = 0**

  IDI= 0 far from obs, IDI~1 in densely observed areas.

$$\mathbf{IDI} = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} + \mathbf{G}\left(\mathbf{S}+\mathbf{R}\right)^{-1} \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$$

- Compare $\mathbf{IDI_Z}$ and $\mathbf{IDI_P}$ with a threshold value: $\mathbf{IDI_{MIN}} = 0.2$

  $\mathbf{IDI_{Z,P}} < \mathbf{IDI_{MIN}}$ then $\mathbf{IDI_{Z,P}}$ = **Z** (zero), otherwise $\mathbf{IDI_{Z,P}}$ = **P** (positive)

Precipitation analysis combining rain-gauge observations with radar estimates

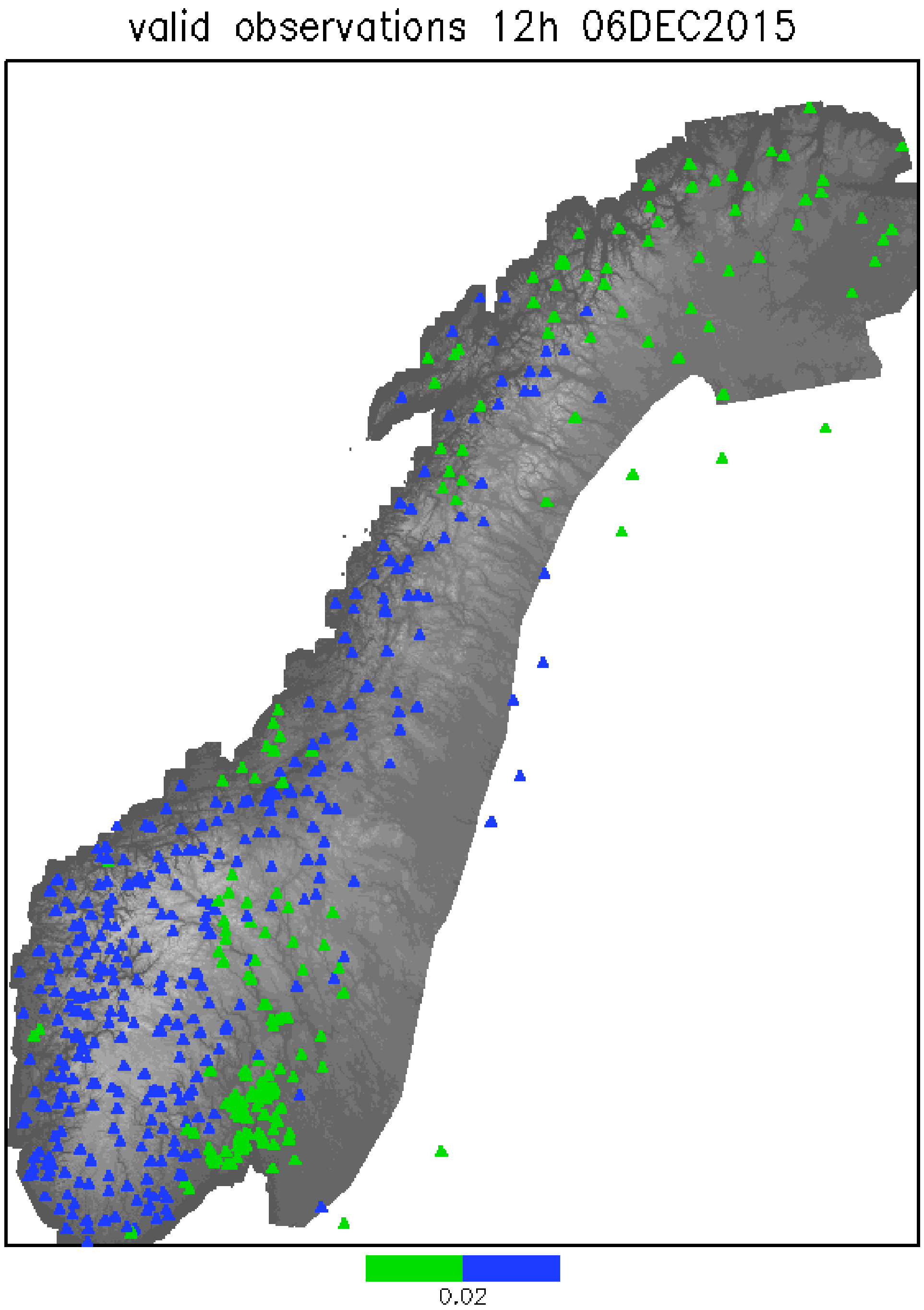
Separate areas: precipitation / no precipitation

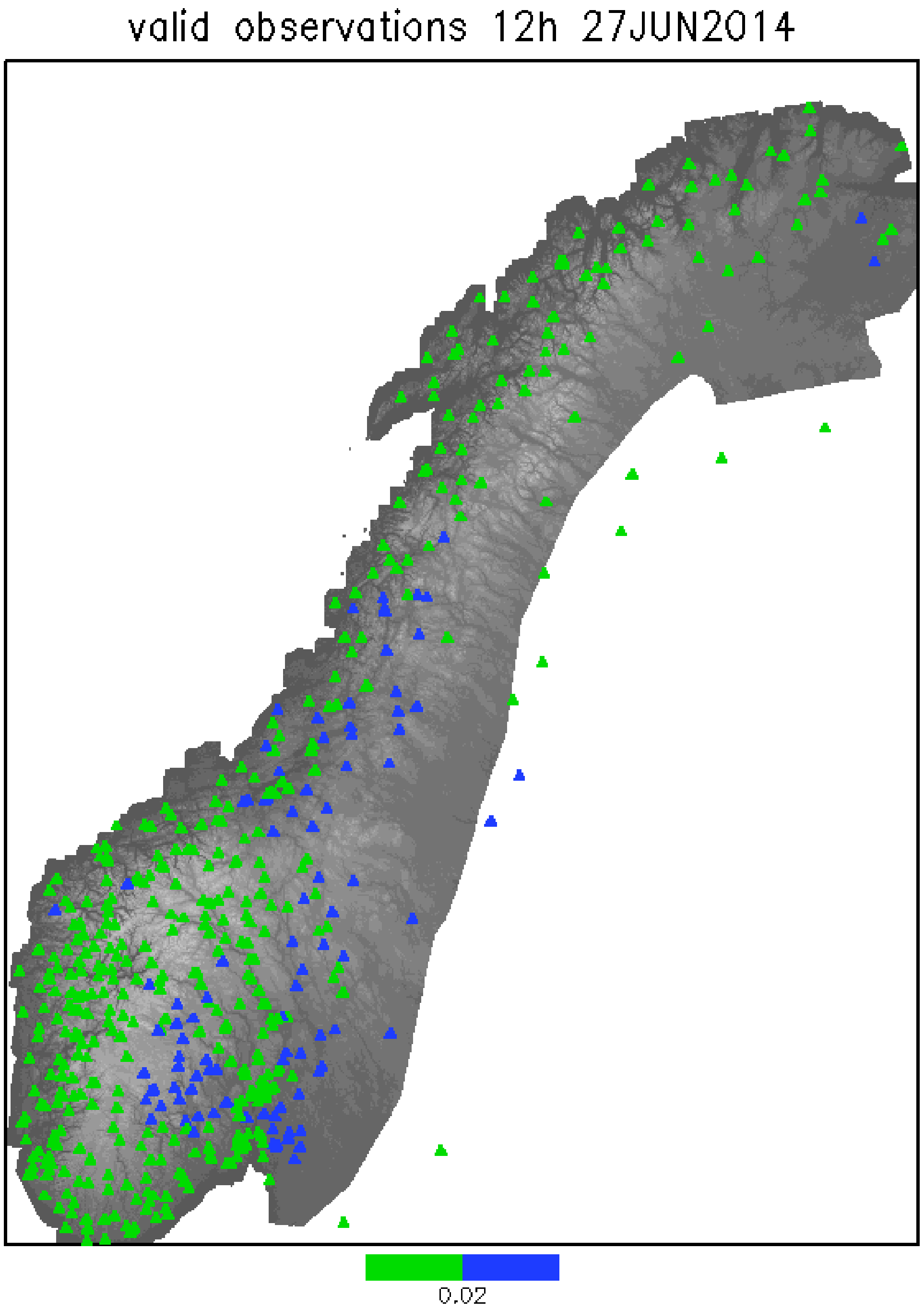
x^b	IDIZ	IDIP	x^a	Do:
U	Z	Z	U	$x^a \leftarrow$ **UNDEF**
U	Z	P	P	$x^b \leftarrow 0$, then **compute analysis**
U	P	Z	Z	$x^a \leftarrow 0$
U	P	P	P	IDIP prevails: $x^b \leftarrow 0$, then **compute analysis**
Z	Z	Z	Z	$x^a \leftarrow 0$
Z	Z	P	P	**compute analysis**
Z	P	Z	Z	$x^a \leftarrow 0$
Z	P	P	P	IDIP prevails: **compute analysis**
P	Z	Z	P	$x^a \leftarrow x^b$
P	Z	P	P	**compute analysis**
P	P	Z	P	$x^a \leftarrow x^b$
P	P	P	P	IDIP prevails: **compute analysis**

$\mathbf{IDI_{Z,P}} < \mathbf{IDI_{MIN}} \Rightarrow \mathbf{IDI_{Z,P}} = \mathbf{Z}$ (zero); otherwise $\mathbf{IDI_{Z,P}} = \mathbf{P}$ (positive); **U = UNDEF**ined value

Precipitation analysis combining rain-gauge observations with radar estimates

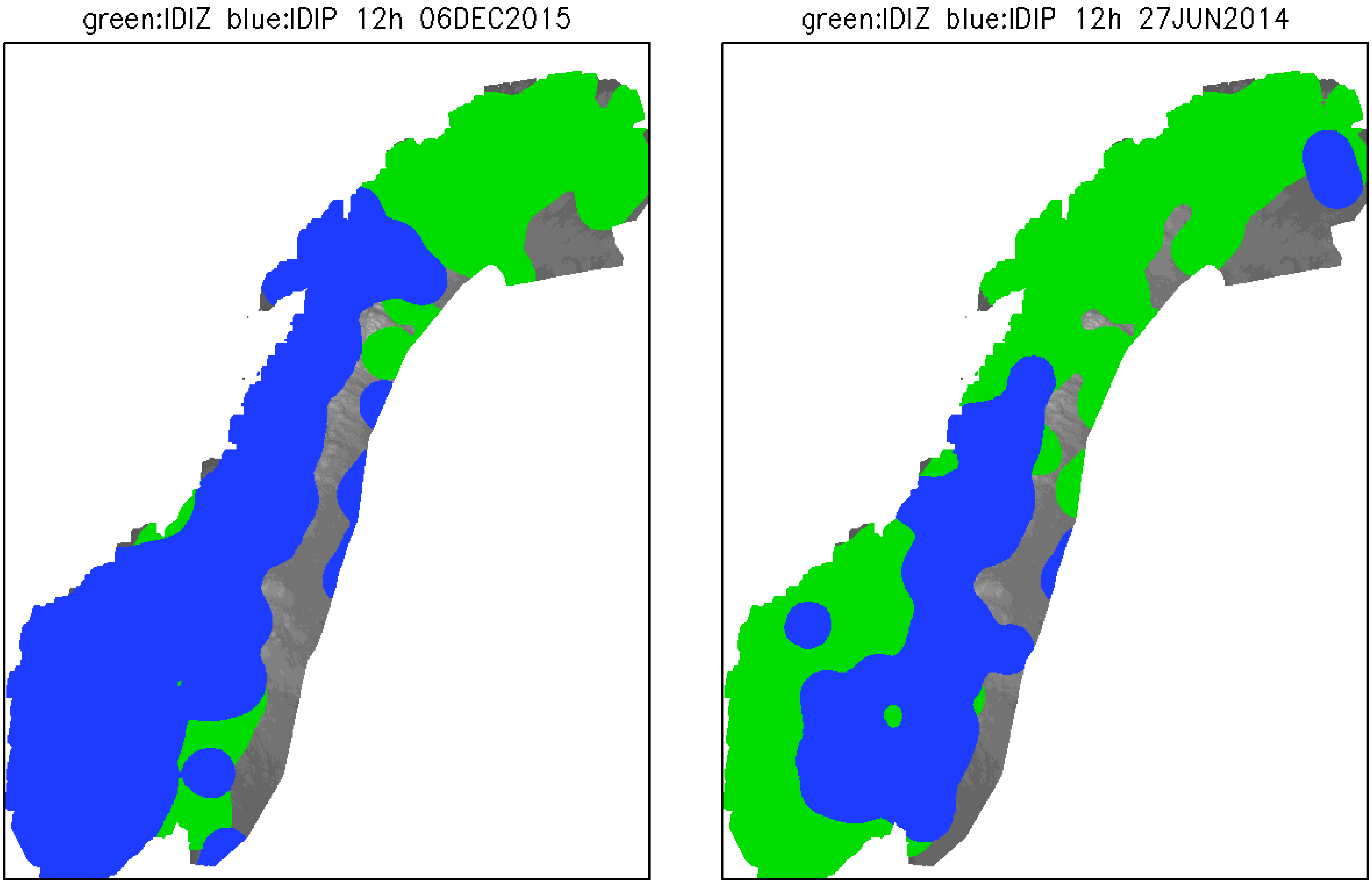
Separate areas: precipitation / no precipitation





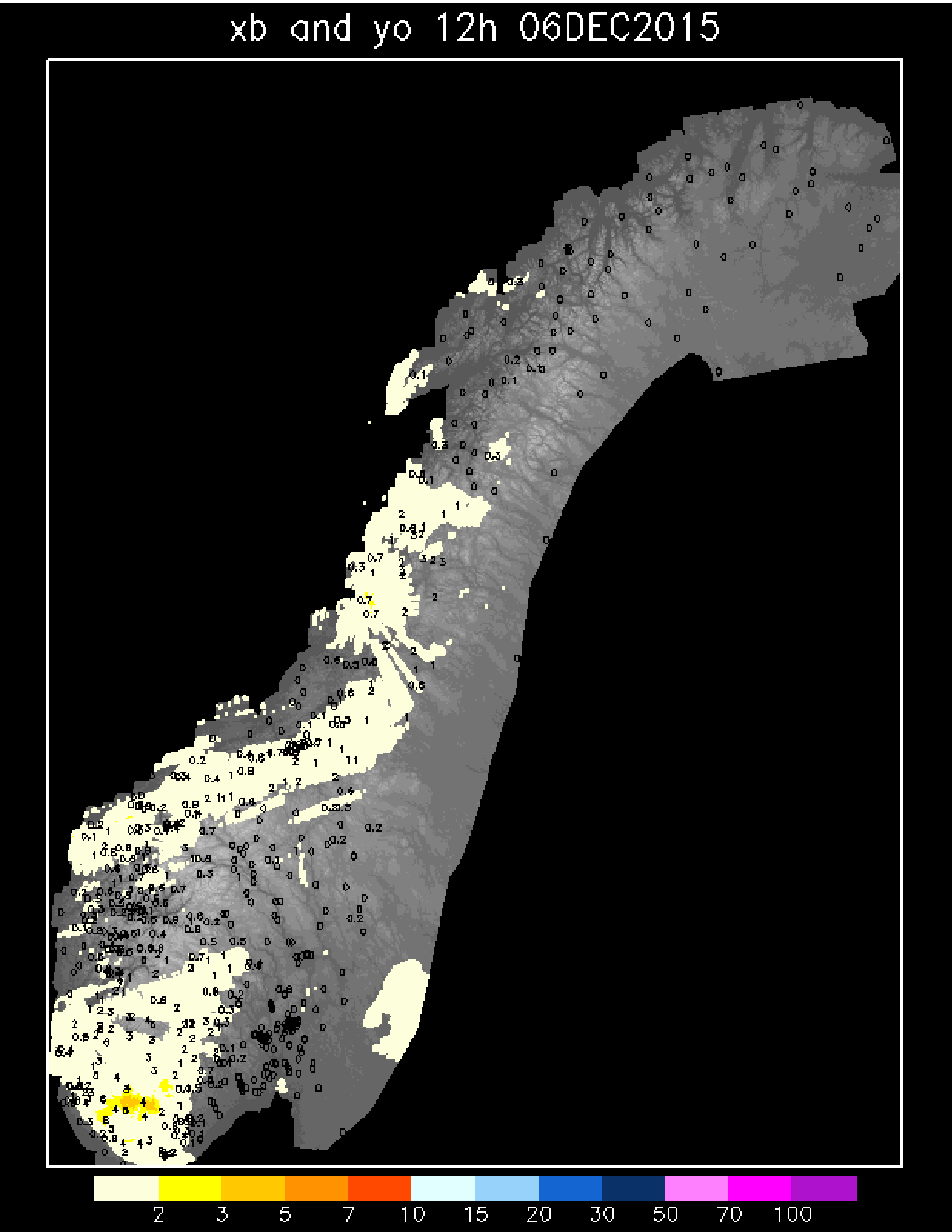
Precipitation analysis combining rain-gauge observations with radar estimates

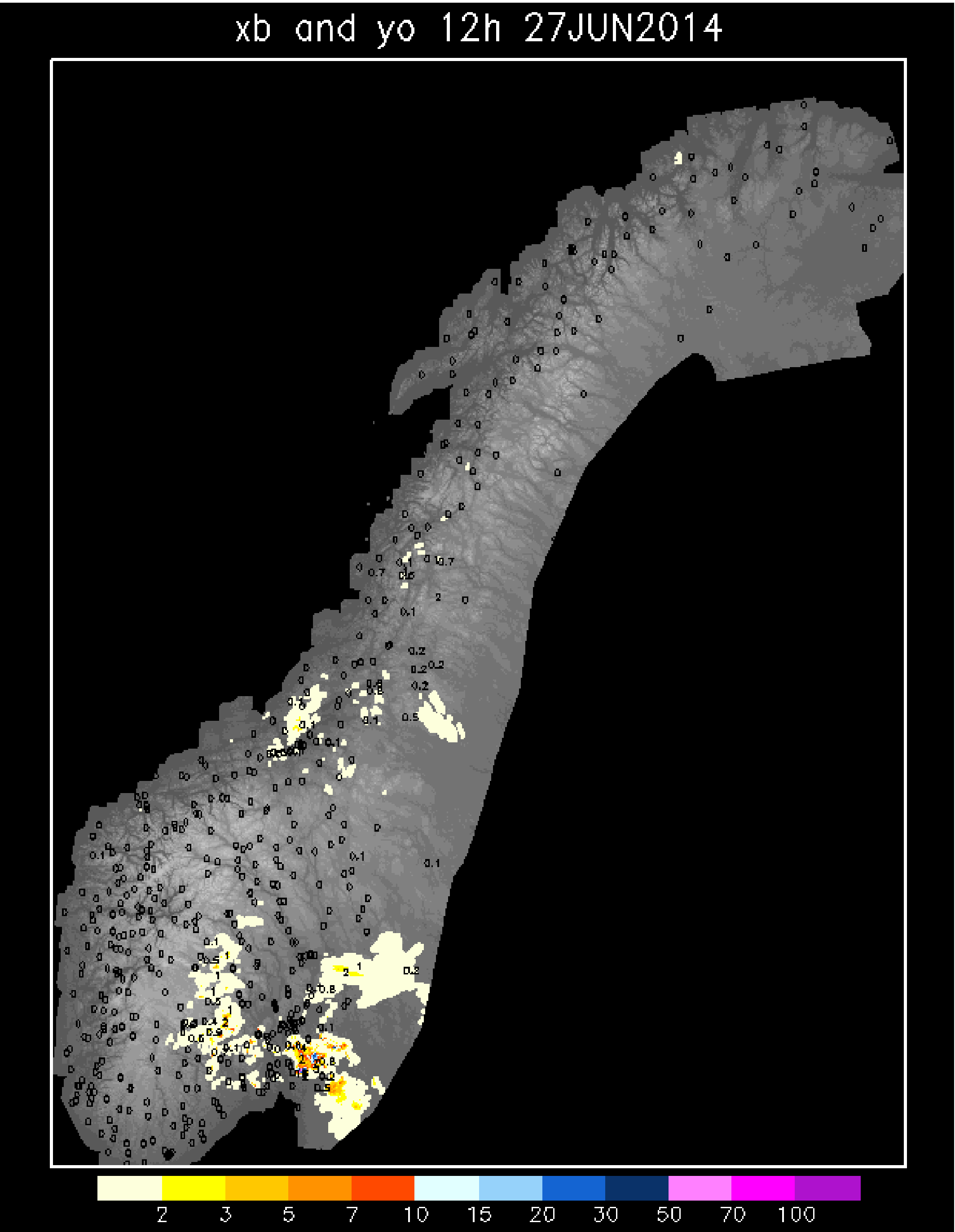
Separate areas: precipitation / no precipitation



Precipitation analysis combining rain-gauge observations with radar estimates

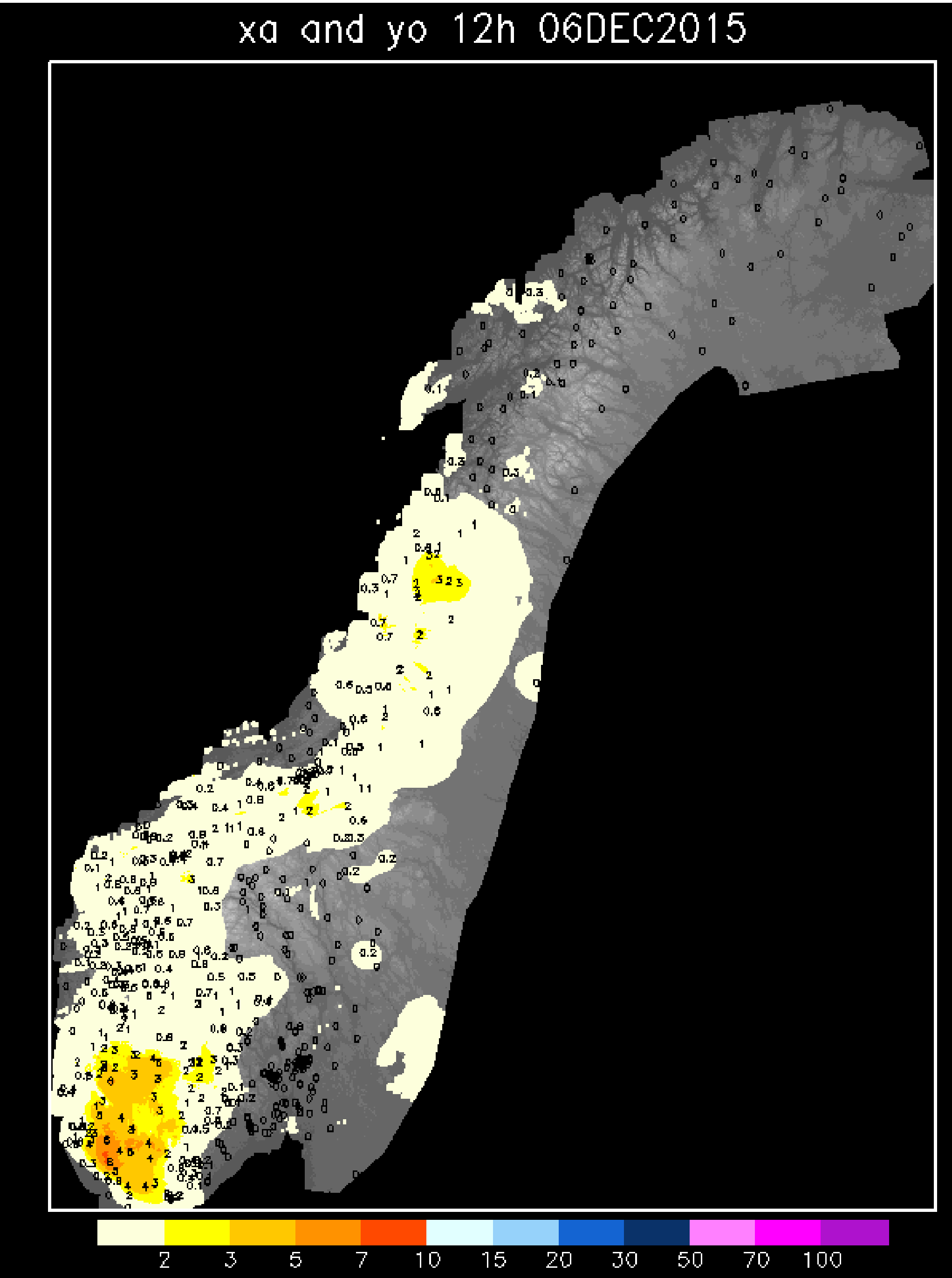
RADAR ESTIMATE = Background and rain-gauge observations

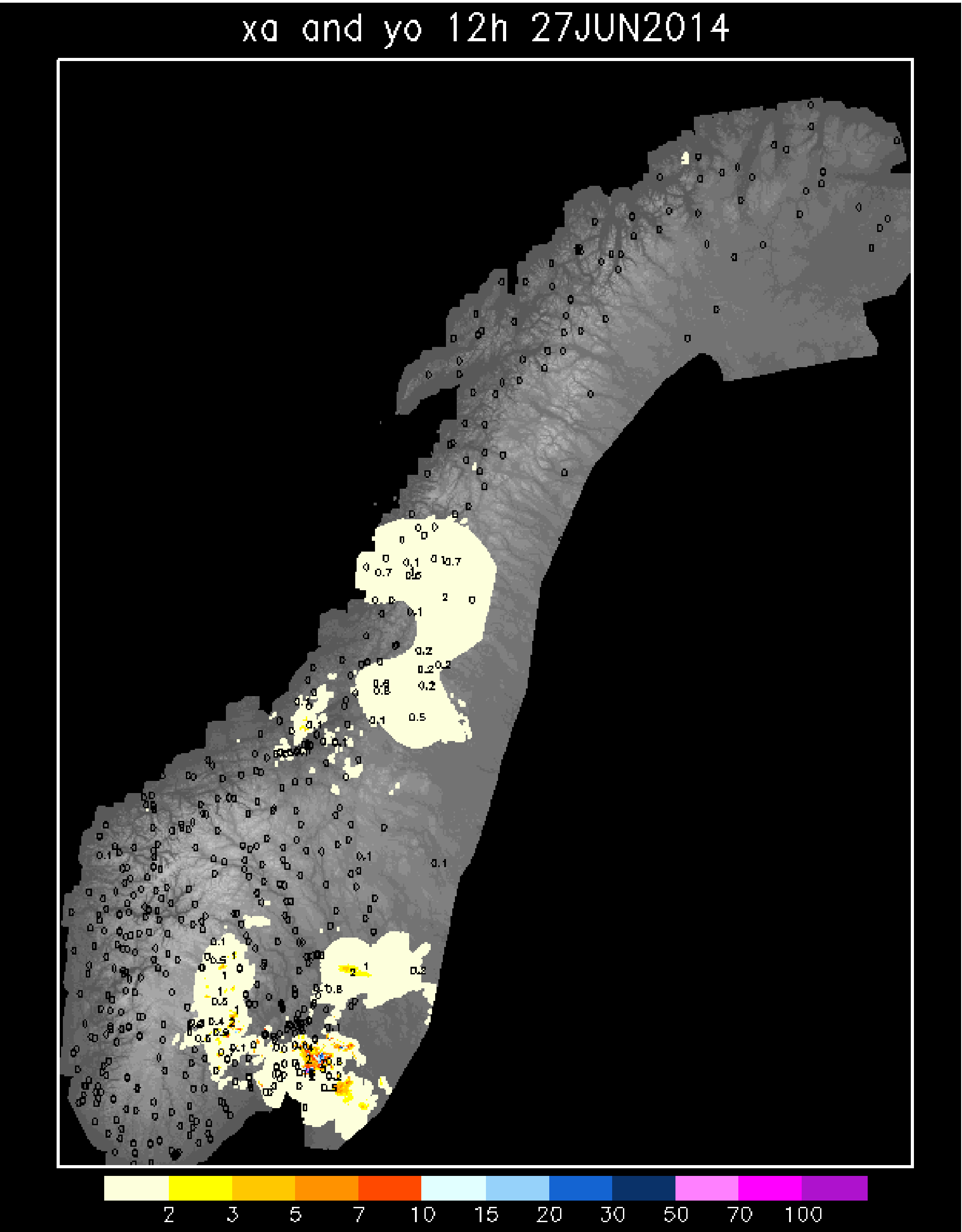




Precipitation analysis combining rain-gauge observations with radar estimates

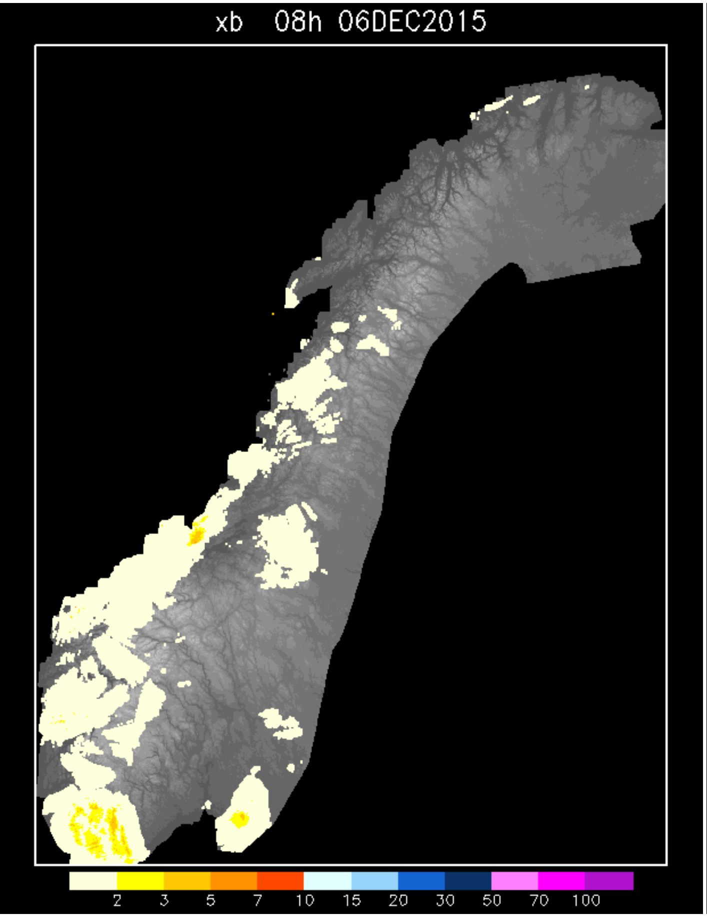
Analysis



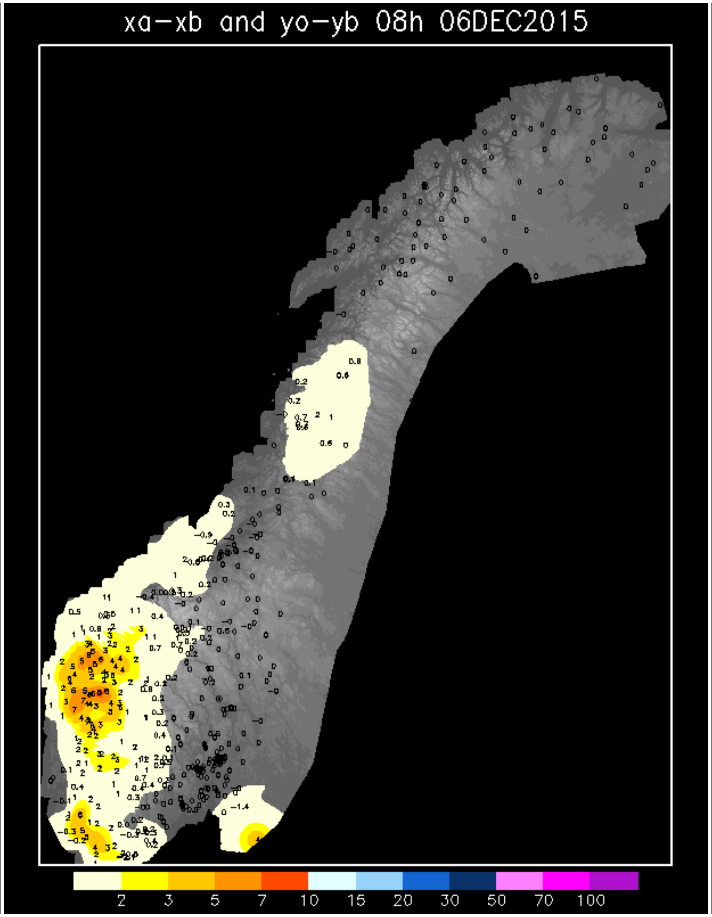


Precipitation analysis combining rain-gauge observations with radar estimates

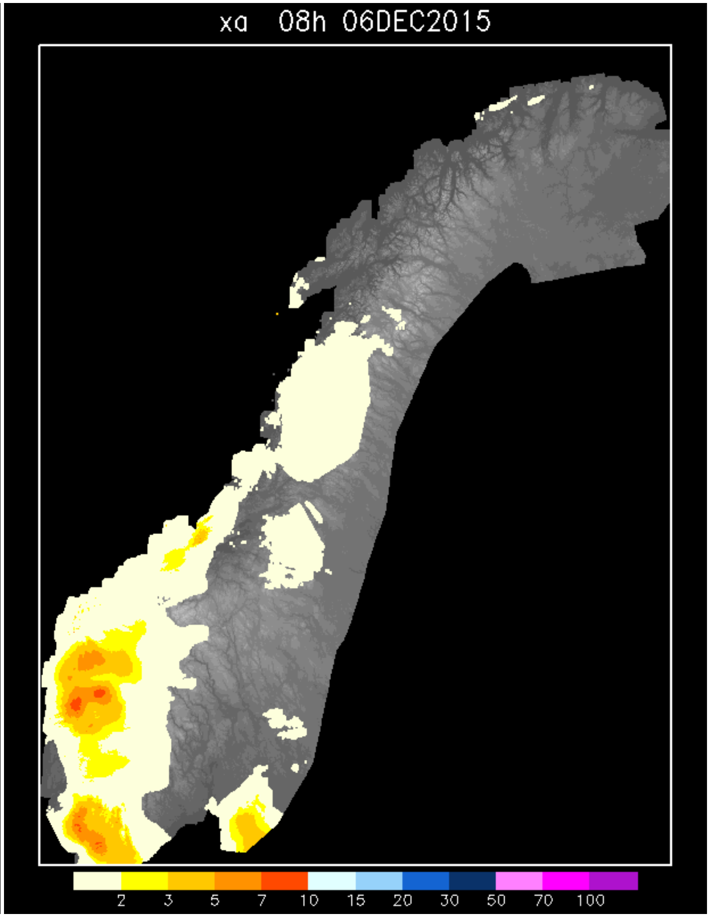
WINTER CASE



Background RADAR estimate



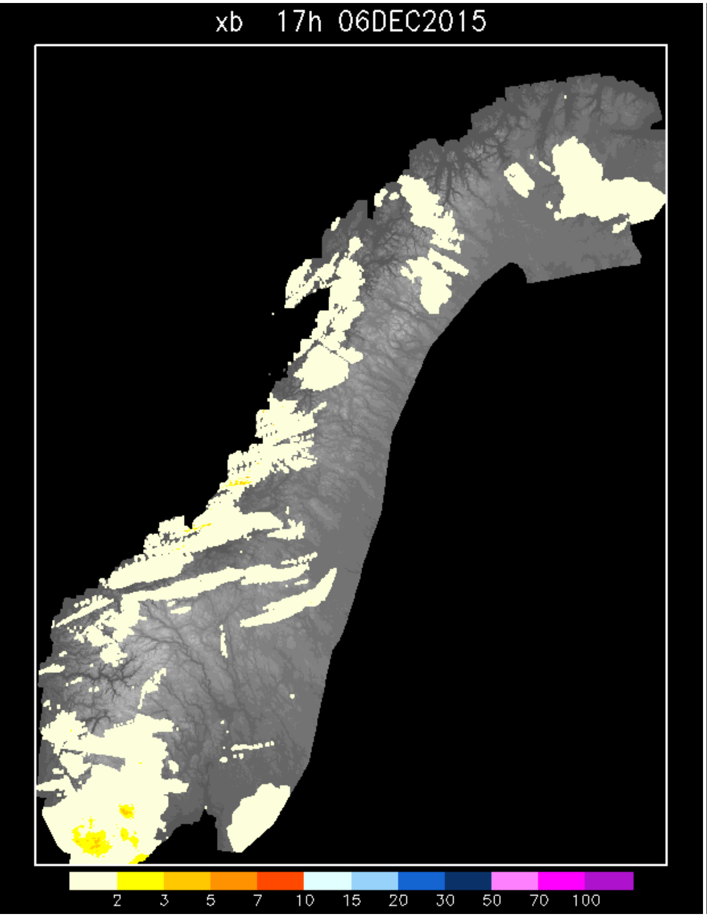
Analysis increment $\mathbf{x}^a$-$\mathbf{x}^b$ and innovation $\mathbf{y}^o$-$\mathbf{y}^b$



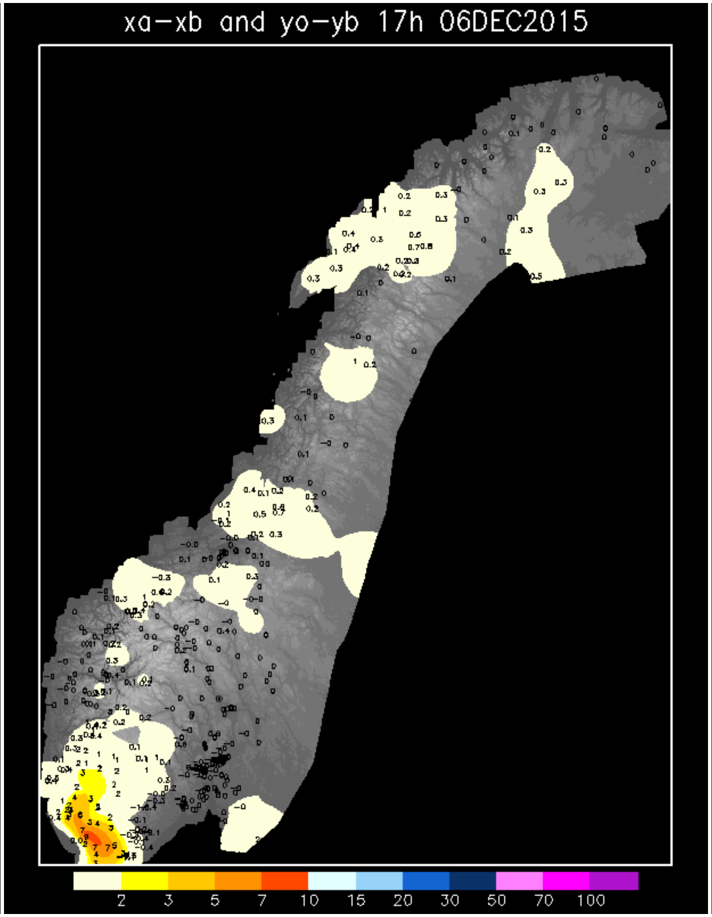
Analysis:
RADAR + RAINGAUGES

Precipitation analysis combining rain-gauge observations with radar estimates

WINTER CASE



Background RADAR estimate



Analysis increment $\mathbf{x}^a$-$\mathbf{x}^b$
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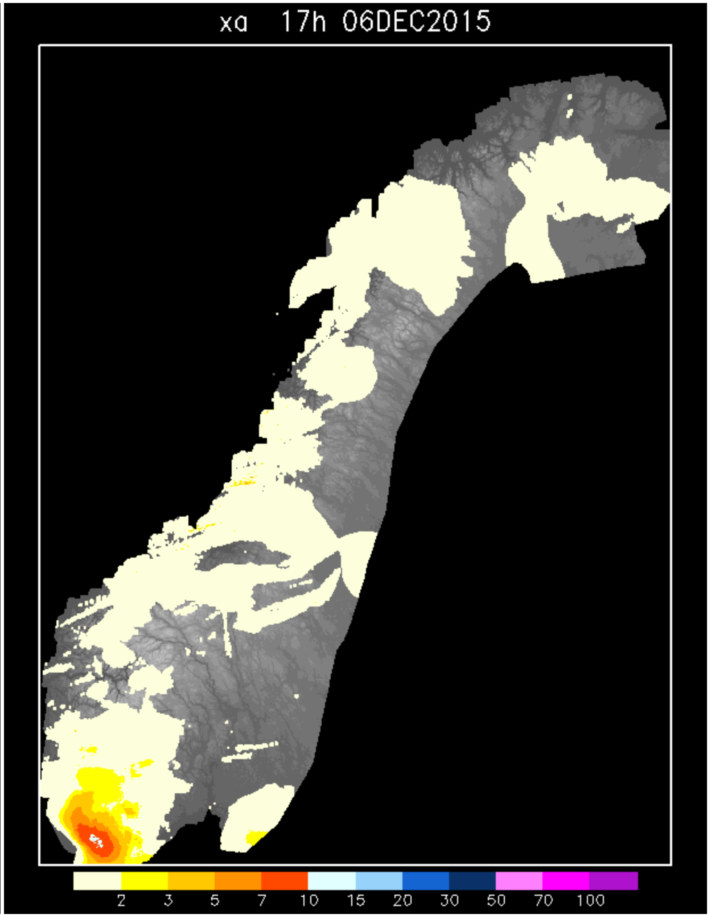

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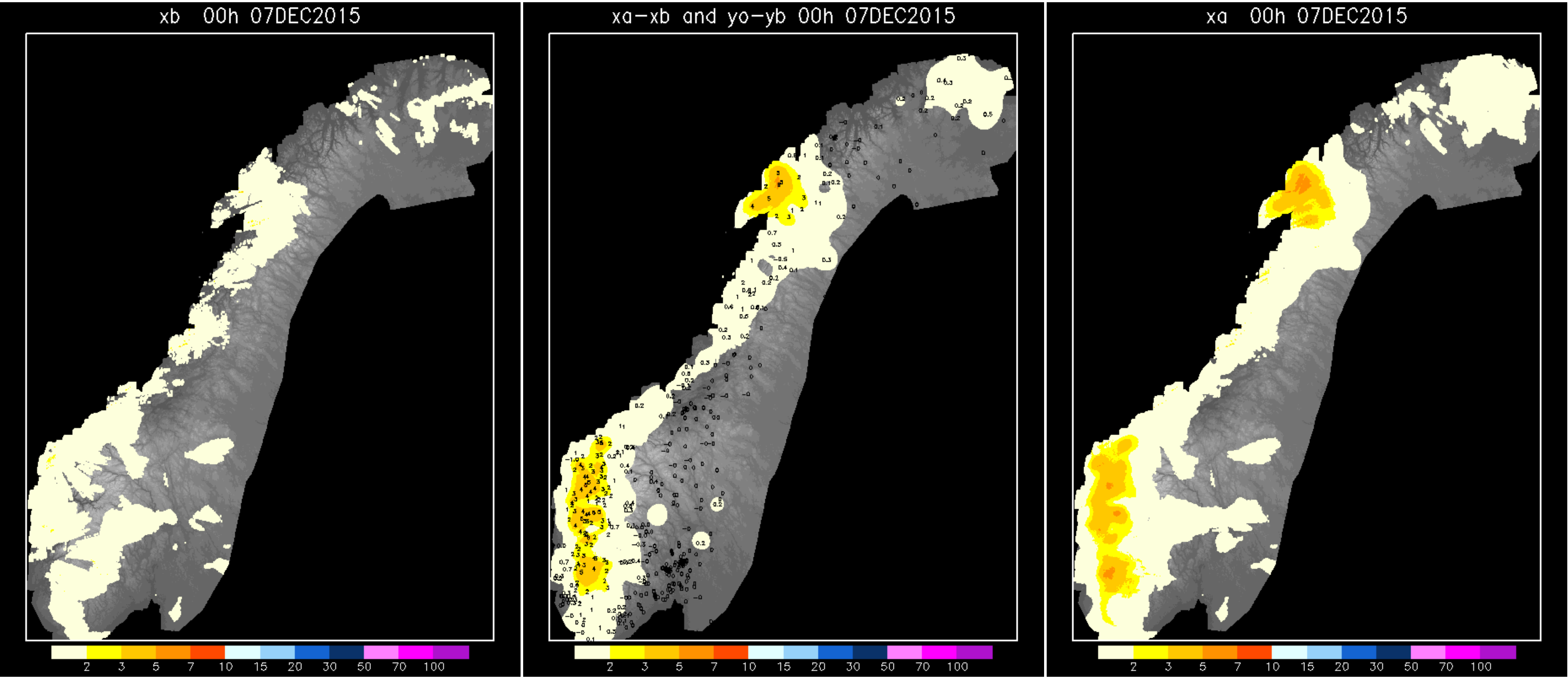
Precipitation analysis combining rain-gauge observations with radar estimates

WINTER CASE



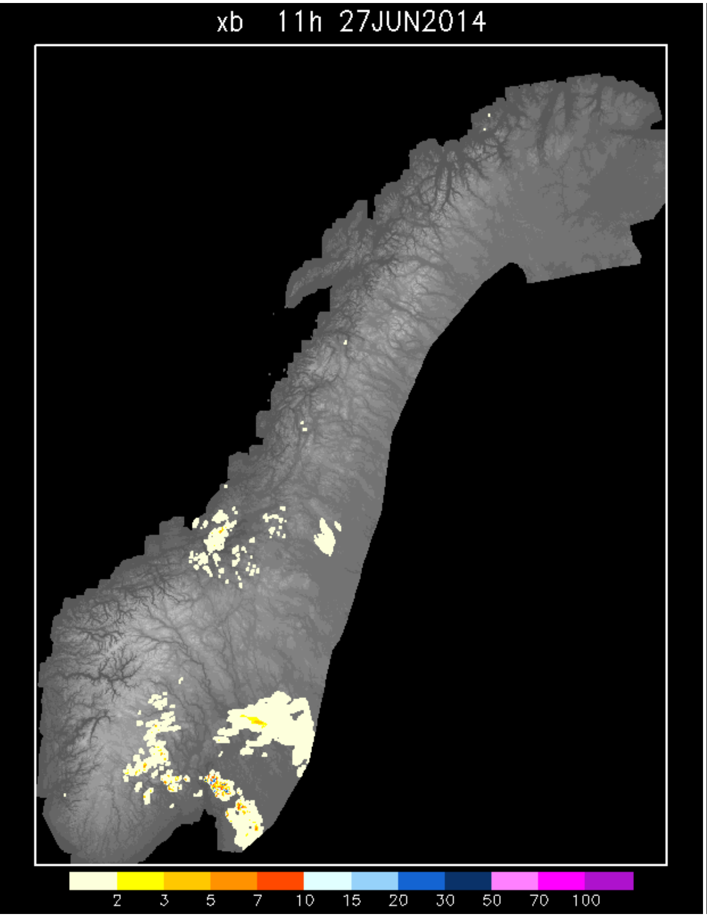
Background RADAR estimate

Analysis increment $\mathbf{x}^a$-$\mathbf{x}^b$ and innovation $\mathbf{y}^o$-$\mathbf{y}^b$

Analysis: RADAR + RAINGAUGES

Precipitation analysis combining rain-gauge observations with radar estimates

SUMMER CASE



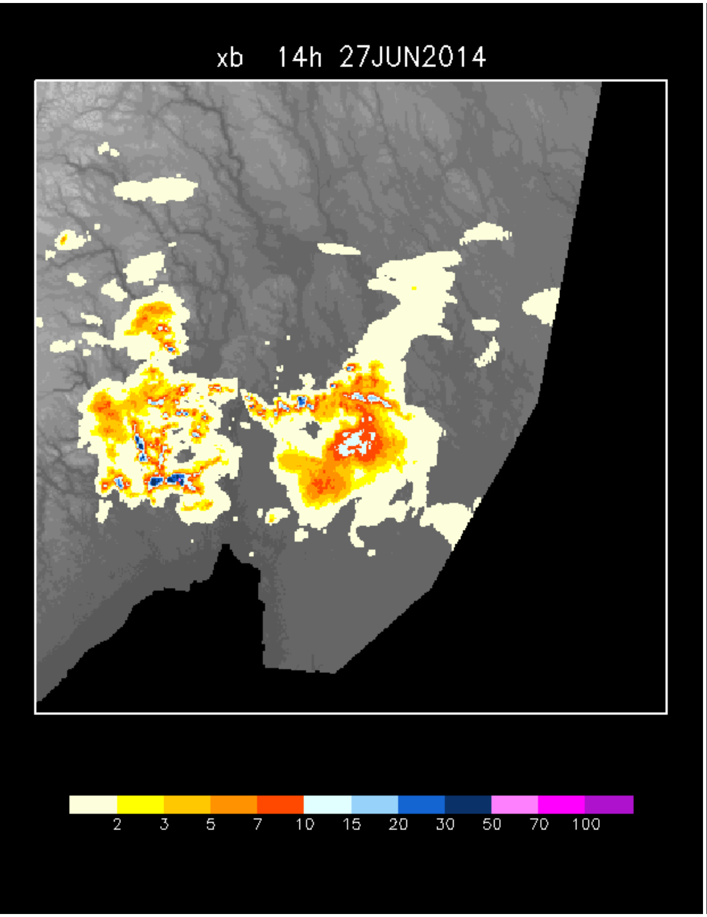
Background RADAR estimate

Analysis increment $\mathbf{x}^a$-$\mathbf{x}^b$ and innovation $\mathbf{y}^o$-$\mathbf{y}^b$

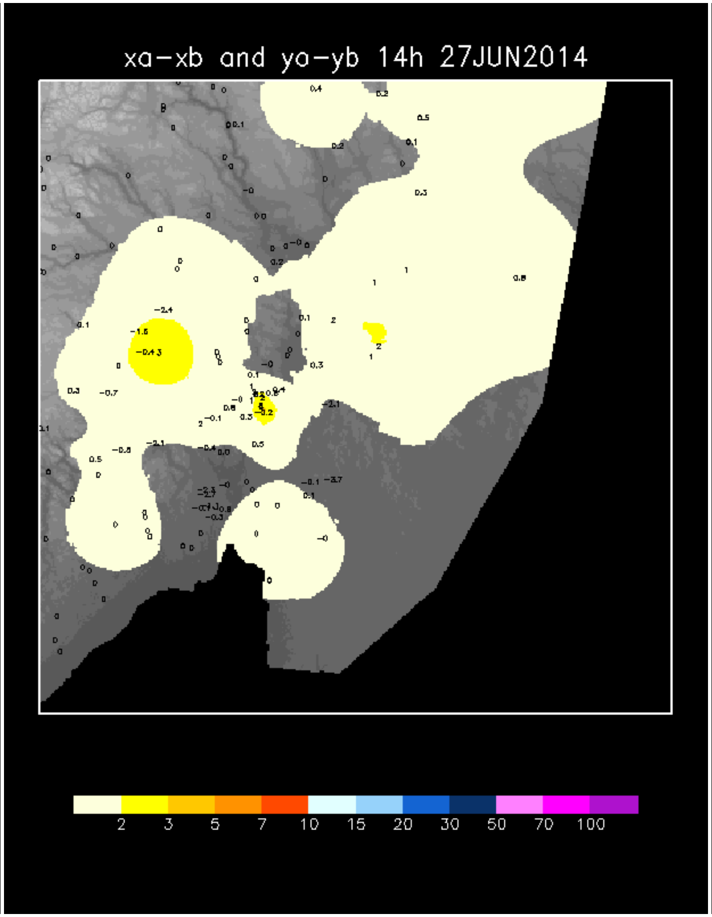
Analysis:
RADAR + RAINGAUGES

Precipitation analysis combining rain-gauge observations with radar estimates

SUMMER CASE



Background RADAR estimate



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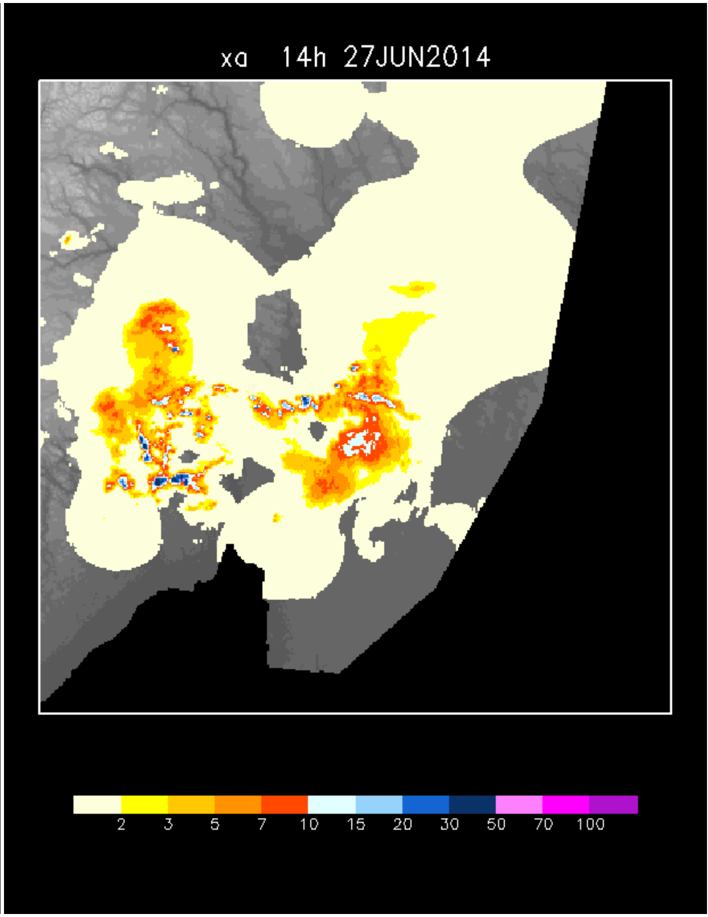

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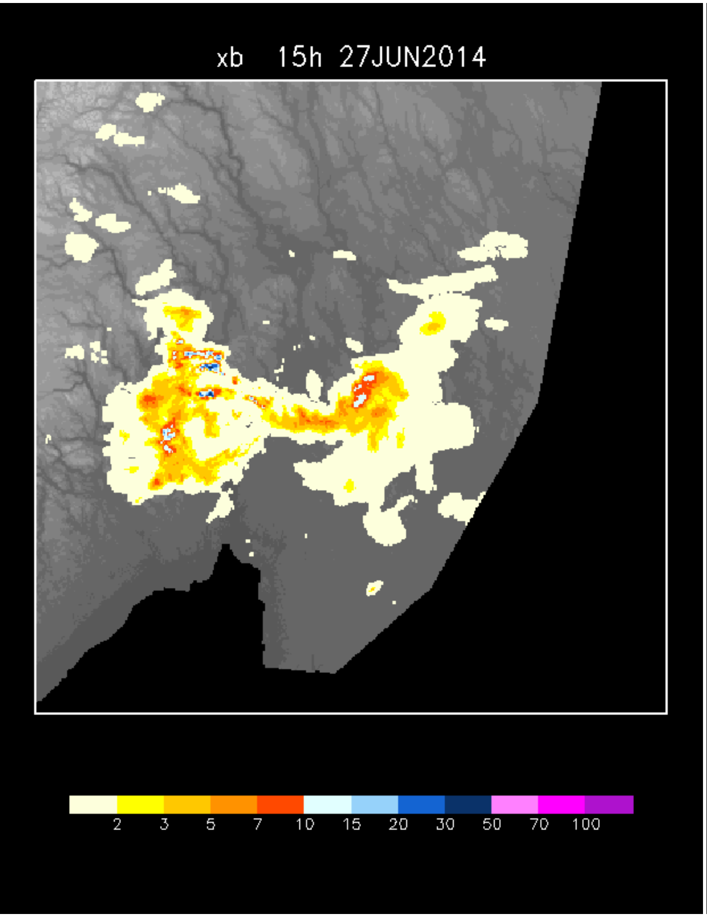
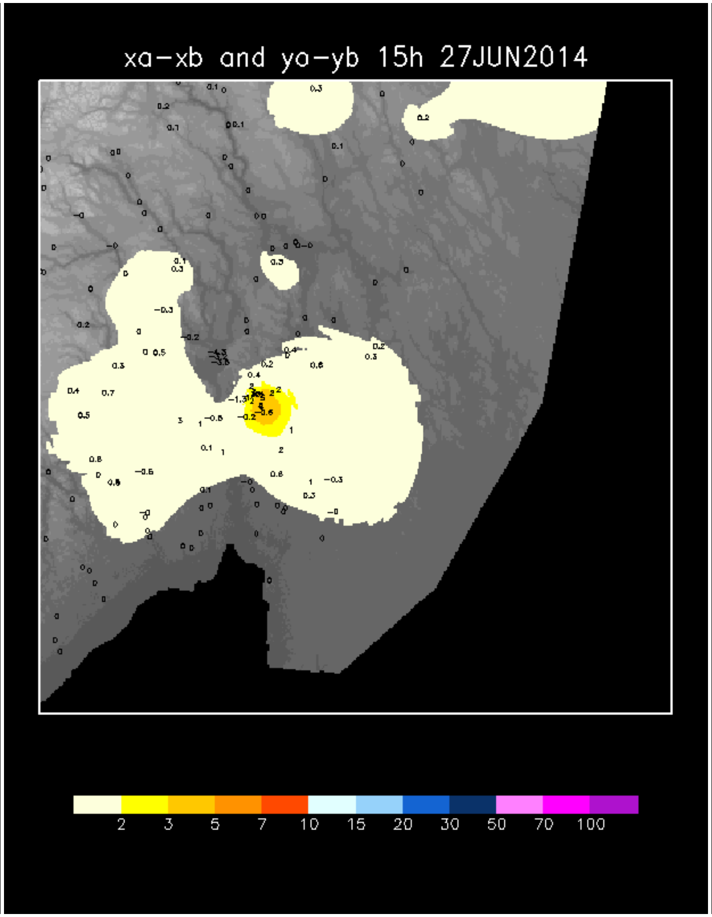


Background RADAR estimate



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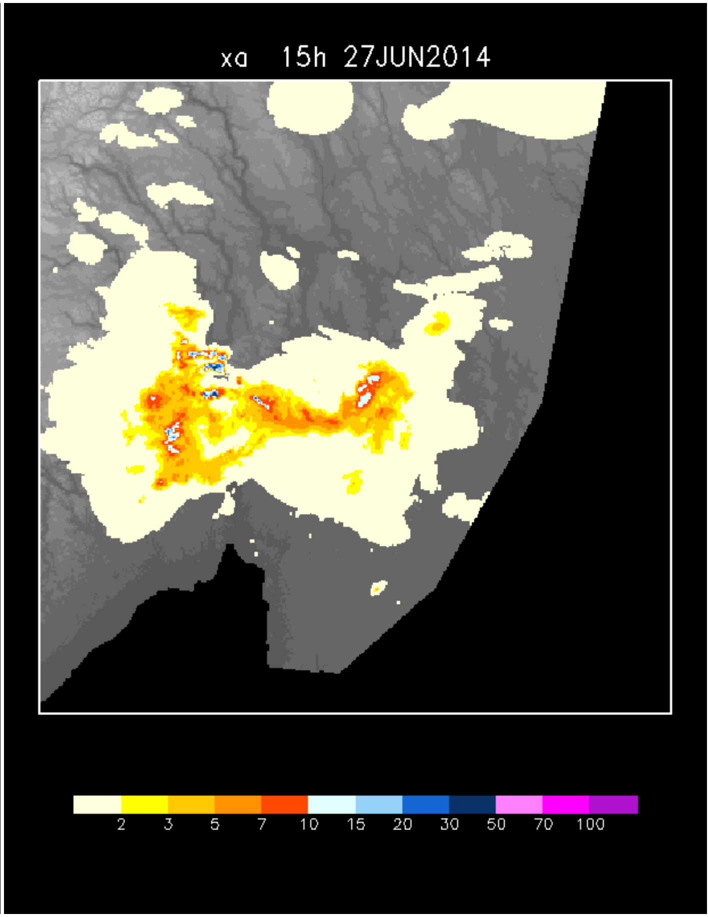
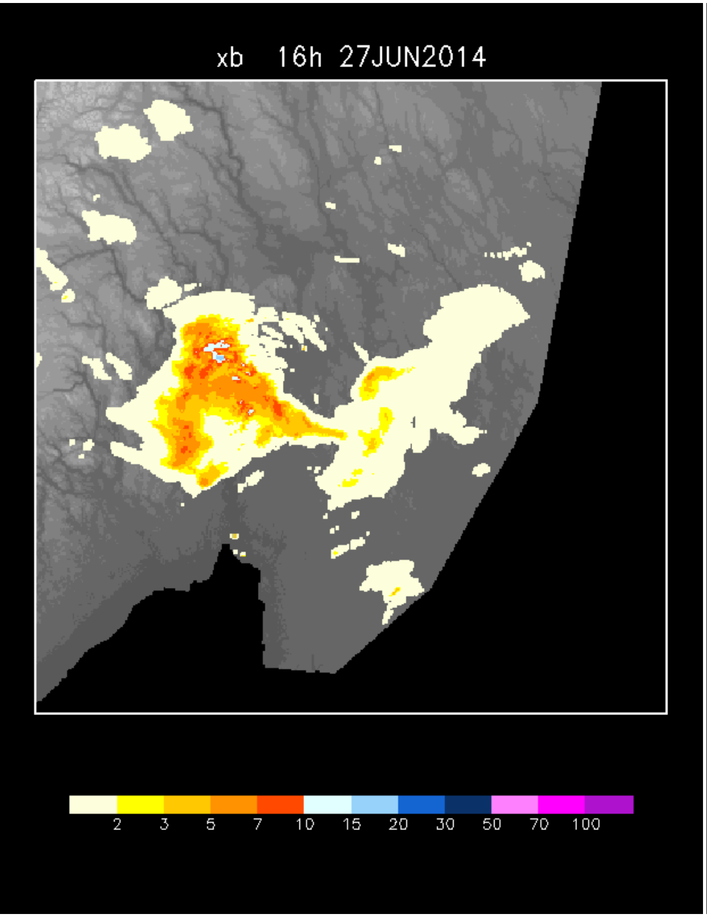


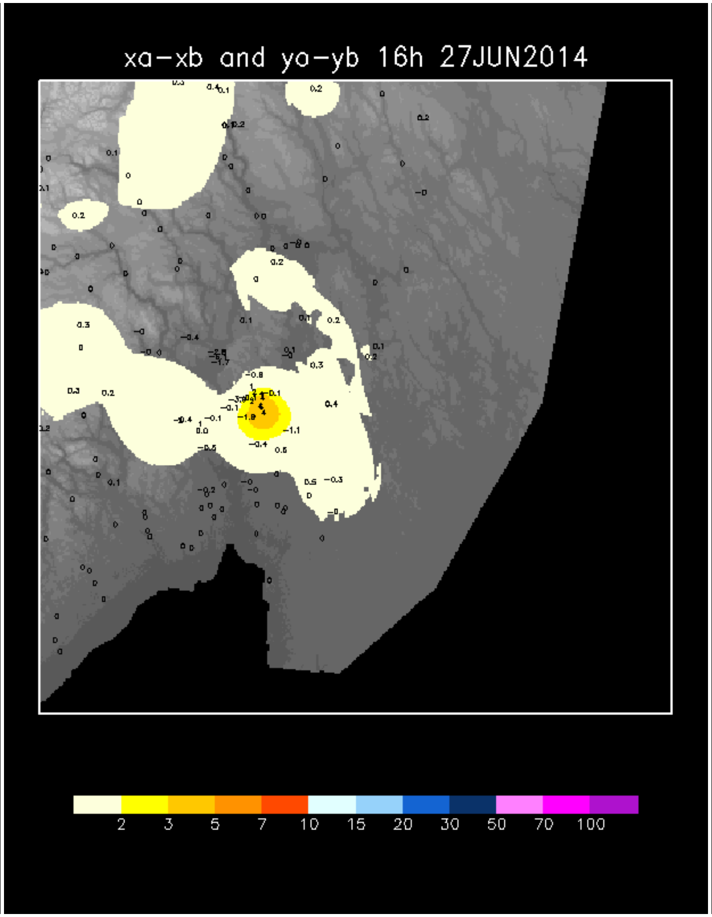
Analysis:
RADAR + RAINGAUGES

Precipitation analysis combining rain-gauge observations with radar estimates

SUMMER CASE



Background RADAR estimate



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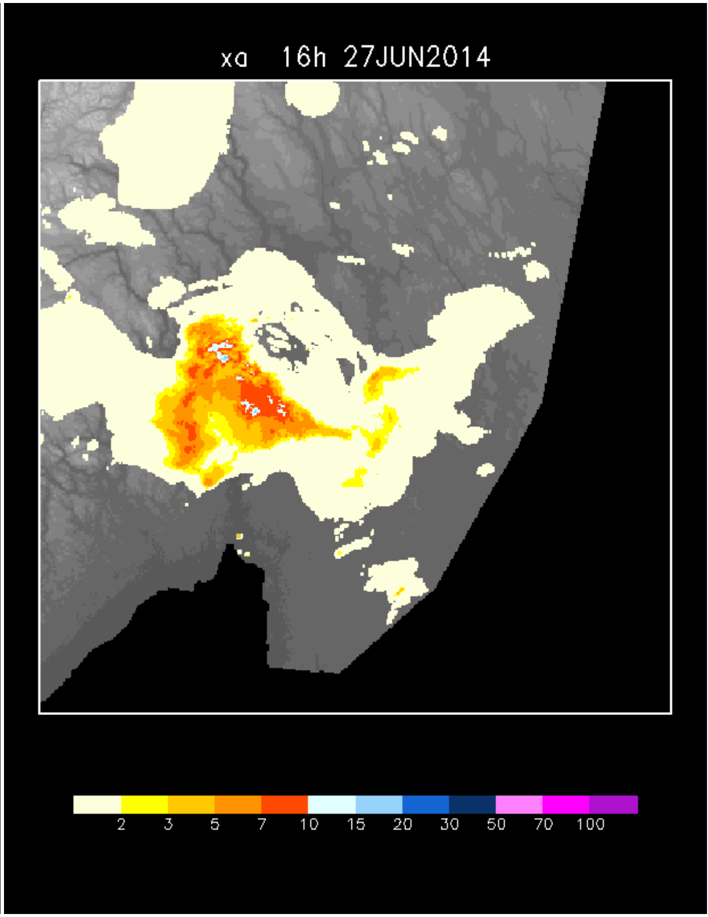

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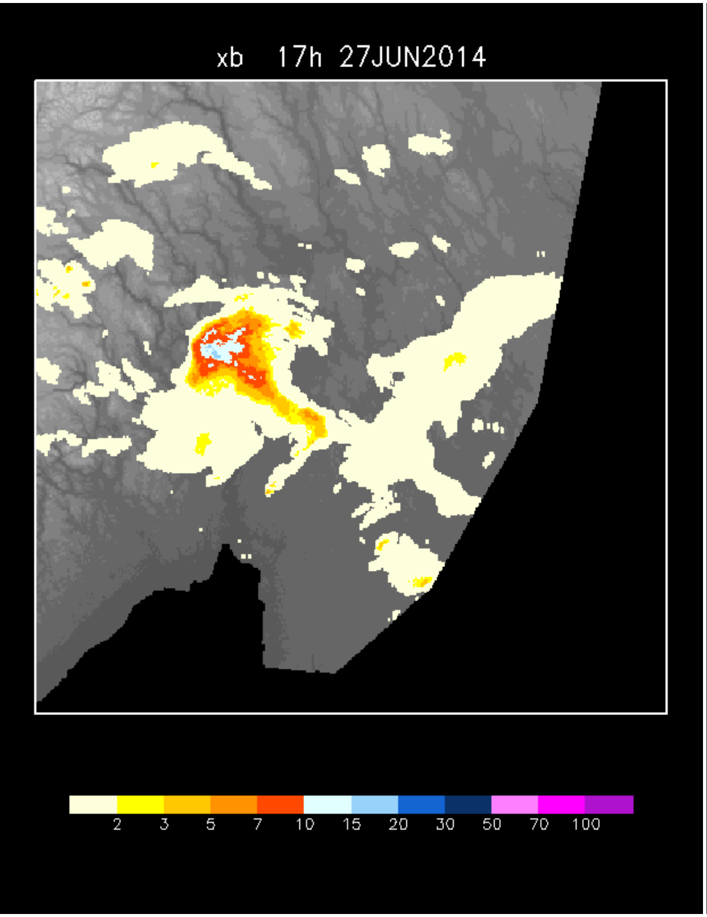
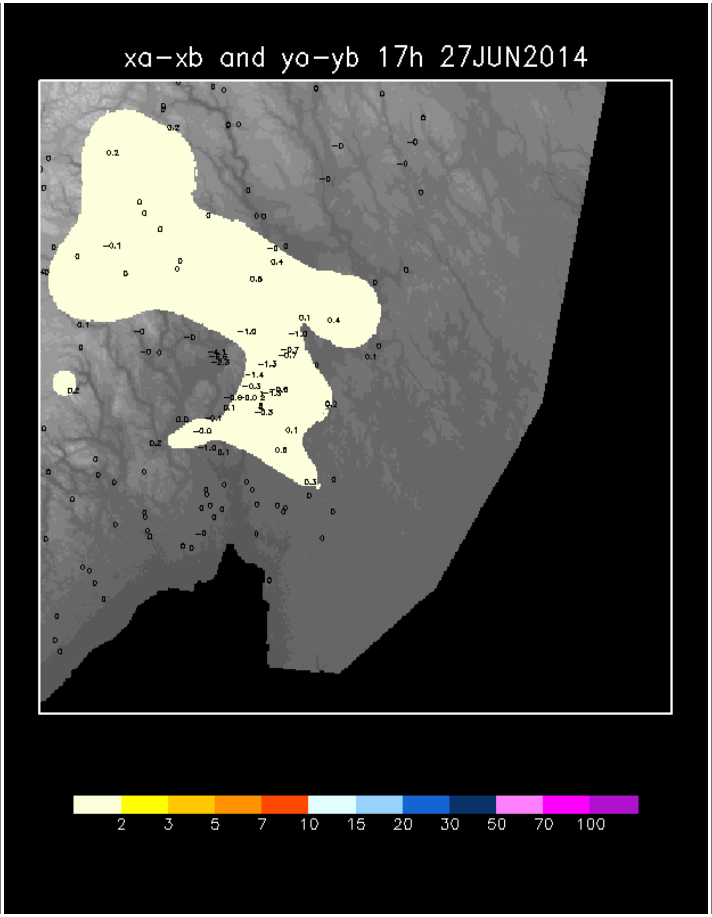
SUMMER CASE



Background RADAR estimate



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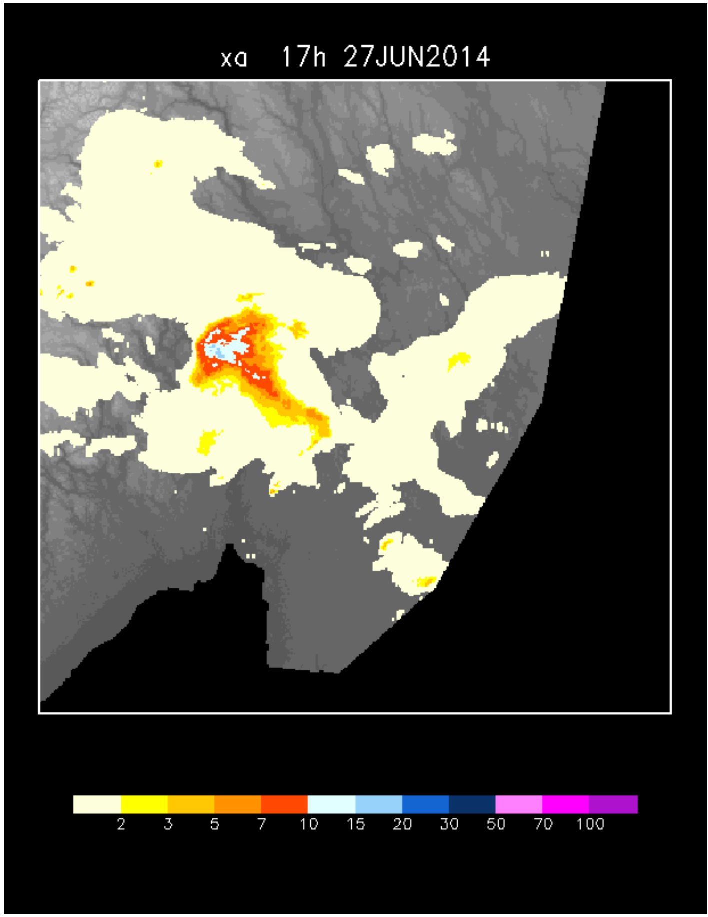
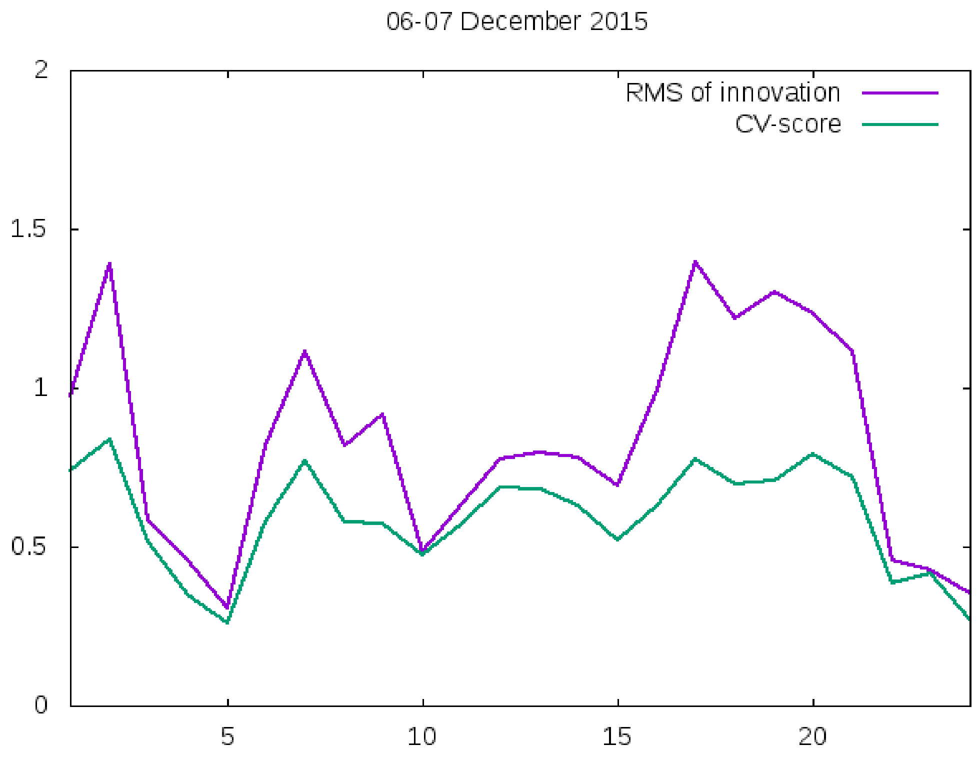


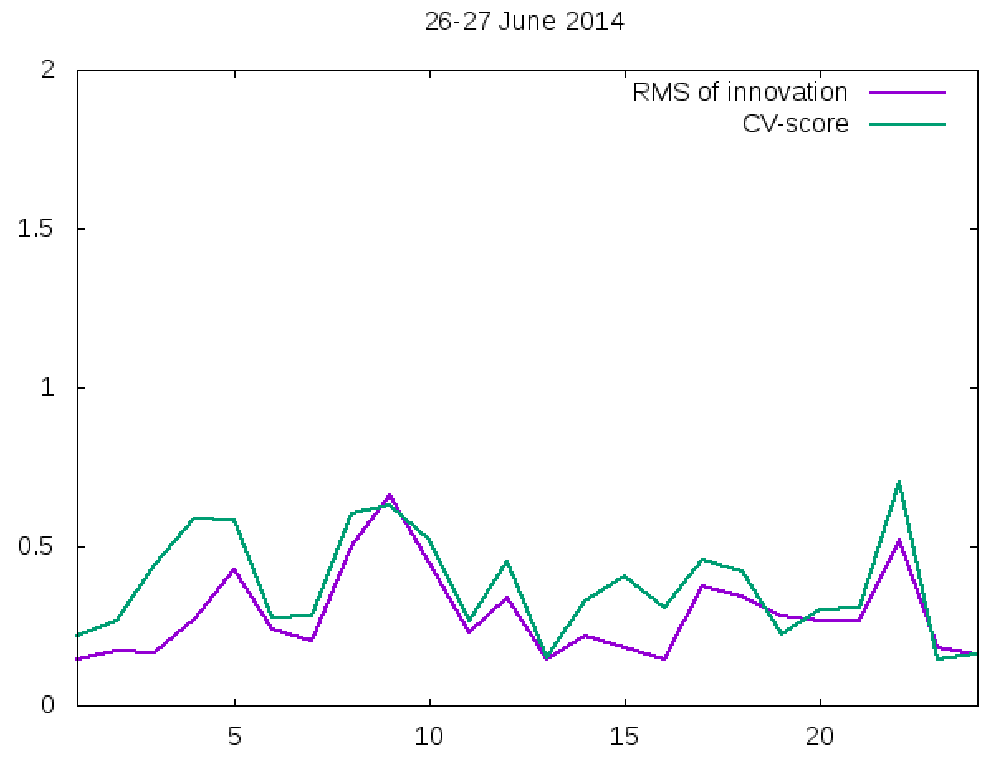
Analysis:
RADAR + RAINGAUGES

Precipitation analysis combining rain-gauge observations with radar estimates

CV-score and RMS of innovation

The CV-score is the RMS residual from the CV-analysis, obtained at each obs location by not using its obsered value, but using all other observations. Compared with RMS residual raingauge-radar.





WINTER CASE
Stratiform precipitation is rather smoothly distributed in space: the CV-score is a meaningful measure of analysis error.

SUMMER CASE
Convective precipitation may happen to be detected by just one rain-gauge: the CV-score may fail as a measure of analysis error.

Conclusions

- Precipitation analysis combining rain-gauge observations and radar estimates
- Operational choices:
  - Separation RAIN/NO RAIN areas
  - Use a raingauge observation only if it exceeds the corresponding radar estimate (“innovative” observation)
  - Optimal Interpolation radar→background, raingauges→observations
- Separation RAIN /NO RAIN areas by means of **IDI** (Integral Data Influence) fields of:
    - “ZERO” observations – less than threshold 0.02 mm
    - “POSITIVE” observation – larger than threshold **and** radar
- Correlation function depending on distance and radar attenuation class
- Raingauge observations compensate for radar attenuation in stratiform cases
- Radar estimation (better than raingauges in convective cases) not degraded by raingauges interpolation
- DEVELOPMENTS: gamma distribution? Include model fields? Change parameters with season? Separate stratiform and convective precipitation?