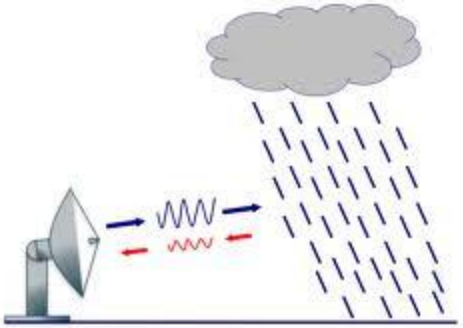
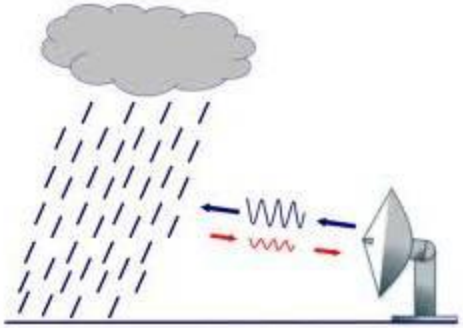
Nowcasting at DMI
based on NWP including assimilation of radar data

emphasis on heavy precipitation





Centre for **M**eteorological **M**odels

DMI

September 2013

CONTENTS

1. Motivation
2. Basic challenges in nowcasting based on NWP
3. Summary of new nowcasting approach at DMI
4. Assimilation and forecast examples
5. Conclusions and outlook

MOTIVATION (1)

1) **Flash floods and other significant precipitation events are expected to be more frequent in a future climate**

2) **On 2 July 2011 Copenhagen was hit by a severe flash flood with large damage : Cost according to ensurance companies : ~3 Billion DKK =400 Million Euro - The operational NWP forecast at the time was not doing particularly well .**

MOTIVATION (2)

3) Numerical weather prediction models can be run sufficiently fast at a high resolution to possibly produce valuable forecasts to the public and authorities in charge of emergency preparedness !

4) New and frequent observations in recent years, e.g. from satellites, radar and air planes are becoming available for NWP and are suitable for very short range forecasts

5) New ideas for Nowcasting based on HIRLAM may be portable to HARMONIE.

BASIC CHALLENGES

- **The significant precipitation phenomena we want to describe and forecast occur partly on very small horizontal scales down to ~1 km which operational models currently cannot properly resolve (*)**

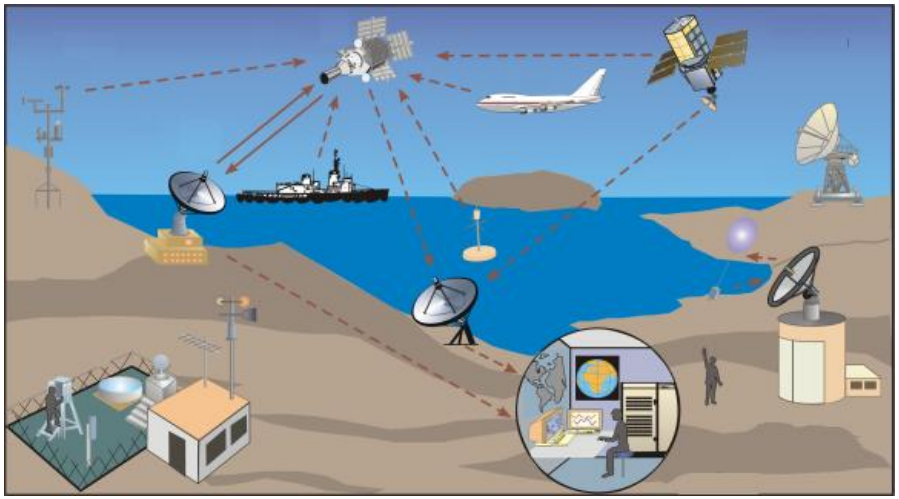
- **Small scale convergent/divergent wind fields connected with small scale precipitation phenomena should ideally be analysed**

- **Difficult to analyse thermodynamic variables consistent with the 3-dimensional wind field. Inconsistencies can easily show up in degraded precipitation forecasts at very short forecast ranges**

- **Data-assimilation and forecast need to run fast due to time constraints.**

[*We may define `Nowcasting´ based on NWP to involve forecasts up to 3 or even 6 hours ahead]

Atmospheric data-assimilation



Examples of data asimilated in model

- Radiances from satellites or derived data
- Wind data from satellites (AMV)
- Radar data (reflectivity or derived data)
- GPS observations translated to vertically integrated humidity
- Radiosonde measurements
  (temperature, wind, humidity from `weather balloons´)
- Surface SYNOP/SHIP/Buoys /Flight measurements

Basic information about current model setup

- **Based on HIRLAM 3 km grid**
- **Rapid update cycles every hour**
- **Assimilation is a combination of 3D-VAR and a new nudging scheme for assimilating clouds and hourly precipitation analysis based mainly on radar data**
- **Monitoring and corrections of radar data not representing precipitation**
- **Nudging scheme is modifying divergent wind in a conceptual approach implying also modification of temperature and humidity**
- **Setup has been run daily for about 9 months in test mode**

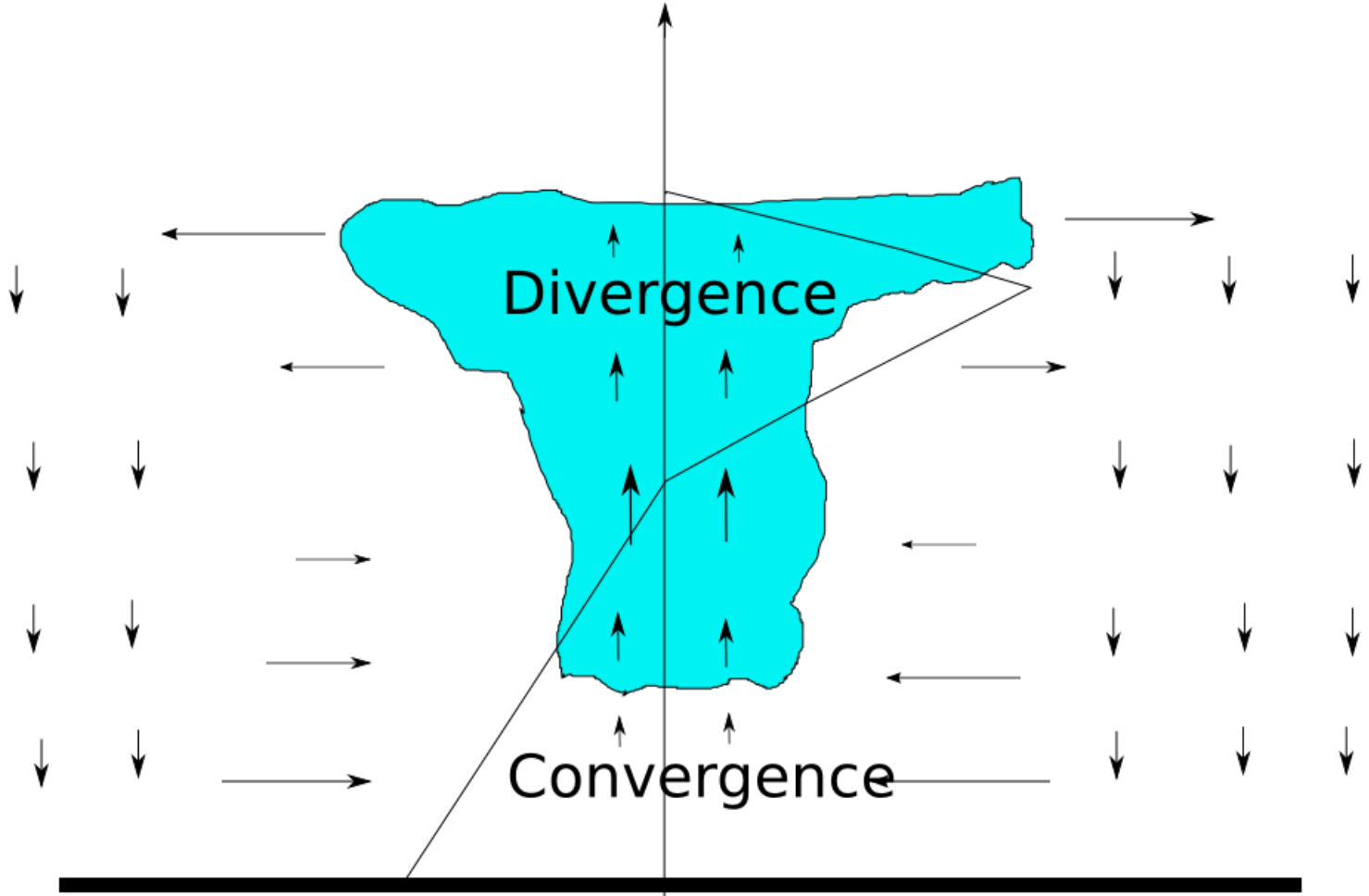
Fast method adapted to Nowcasting purposes

- **Adjustment of wind field to precipitation (new method developed at DMI)**

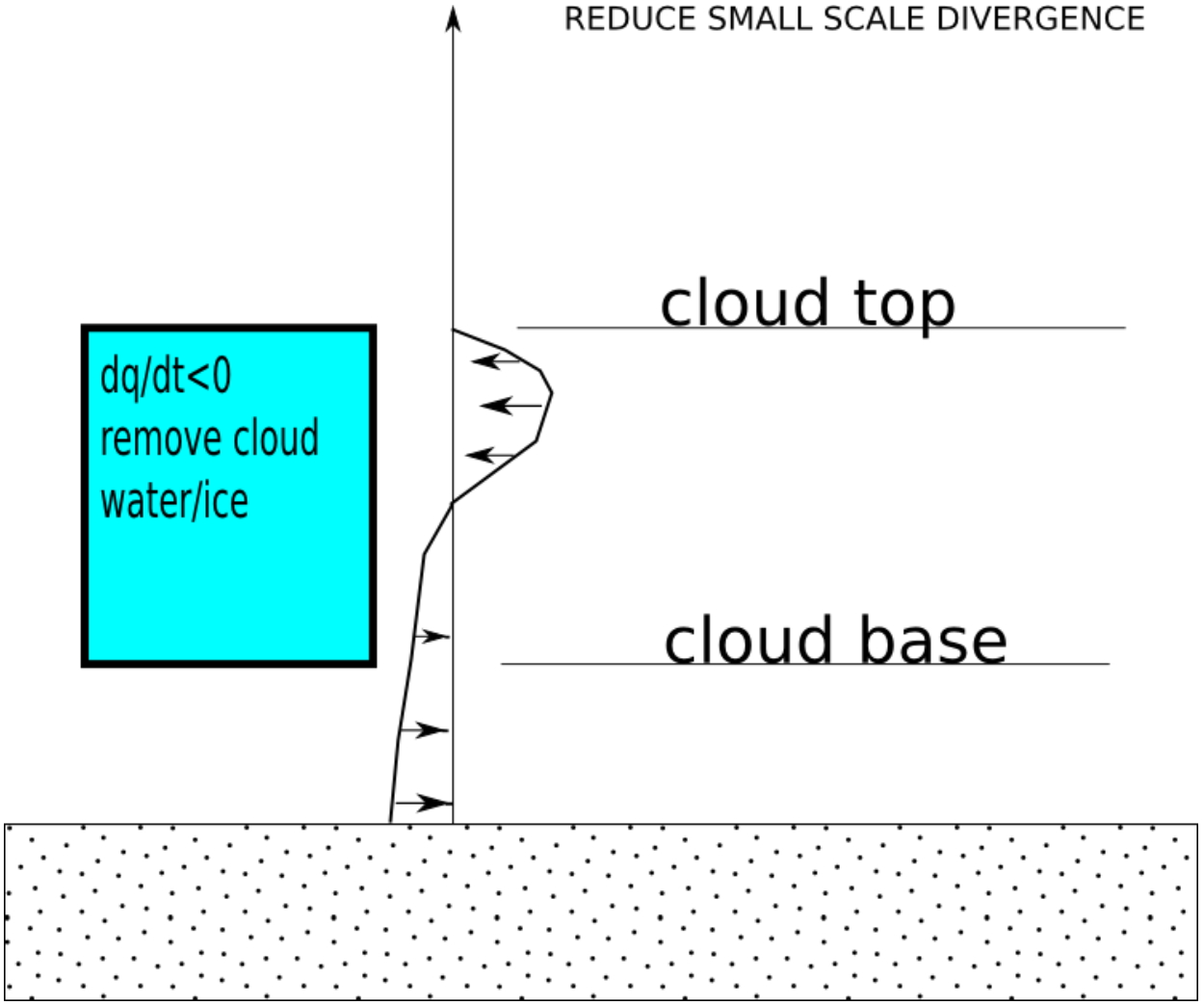
  This method also adjusts model state according to differences between forecast precipitation intensity and observed of analysed intensity `continuously´ during some assimilation period. In contrast to Latent heat nudging both temperature, humidity variables and wind field are adjusted searching for better model consistency.

  The developed method has been presented at the annual EGU (European Geophysical Union) meeting in Vienna 2013.

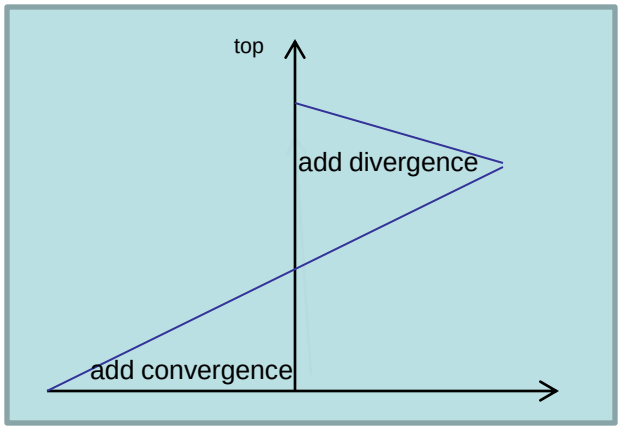
Assimilation of radar data
Increase precipitation



Assimilation of radar data
Decrease precipitation



adjustment procedure



The vertical integral of added convergence and divergence is zero implying no surface pressure change as a result of extra precipitation. This is based on an observational experience that surface pressure changes are small as a result of precipitation release

Higher humidity at low levels compared to humidity a high levels implies that the method is able to supply a net source of moisture for generation of additional precipitation The picture is consistent with a classical conception of convection with convergence at low elevations and divergence at high elevations.

$$\int_{bot}^{top} q(z)\,\delta D(z) = K\,(Pm - Pa)$$

Adjustment Nomenclature

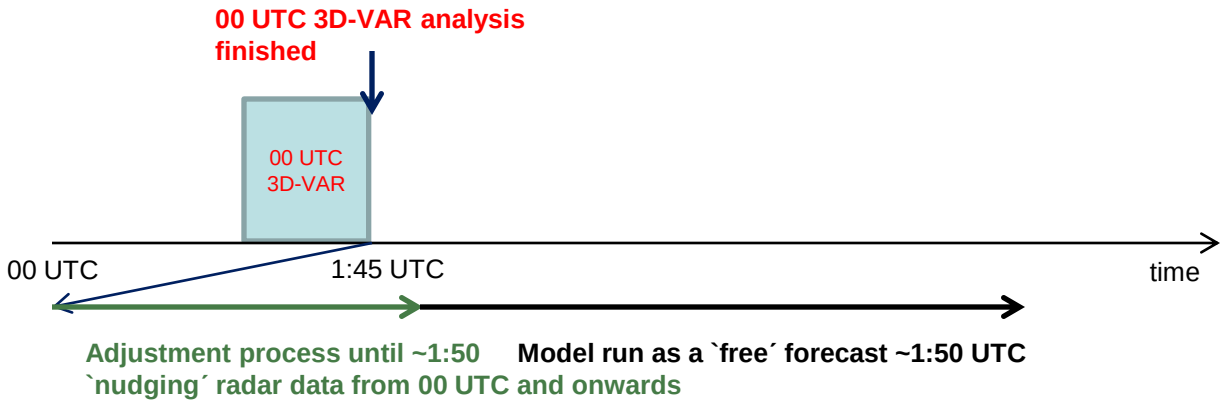
Pm is the model precipitation rate

Pa is the analysed precipitation rate

q(z) is current model specific humidity

δD(z) is imposed change of divergence as a prescribed function of height

Current DMI data assimilation with radar data



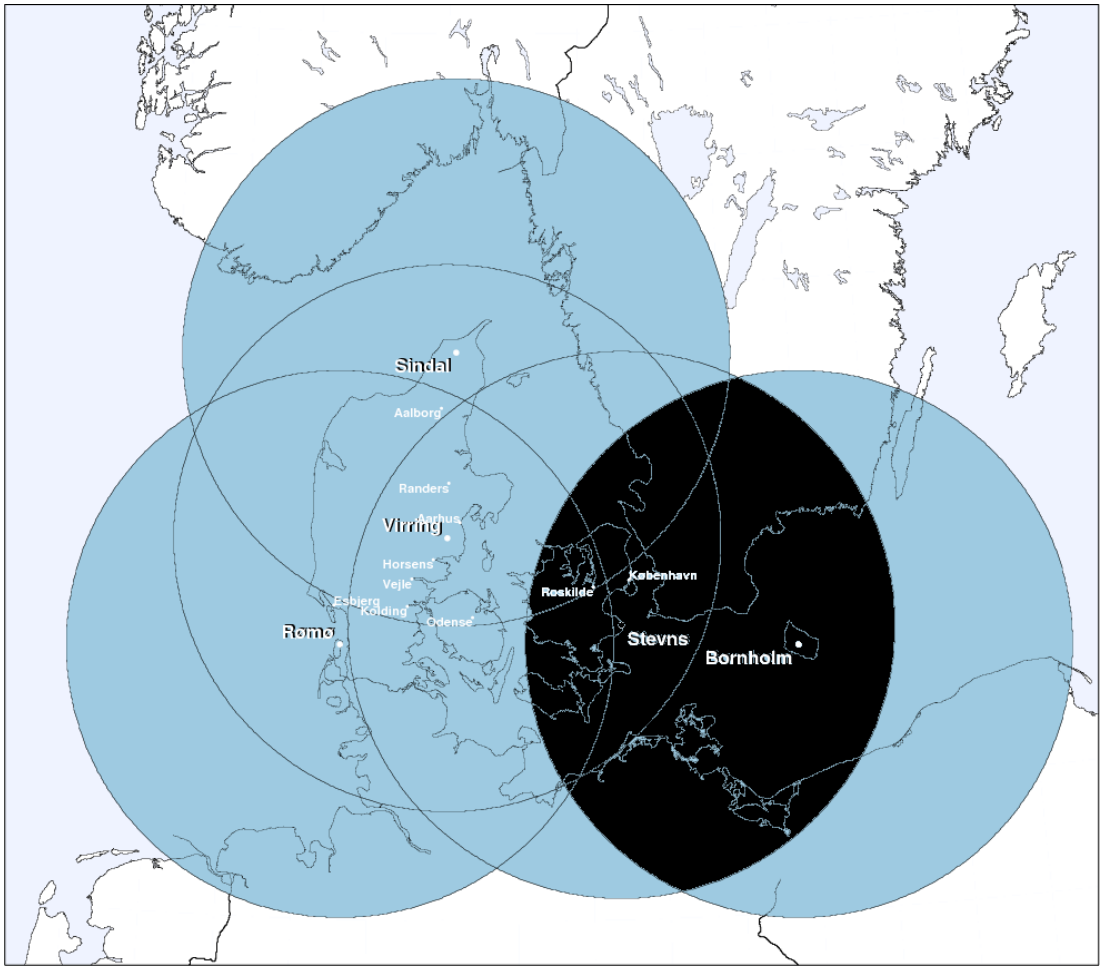
DMI Radar network

`old radars´:
Sindal
Rømø
Stevns

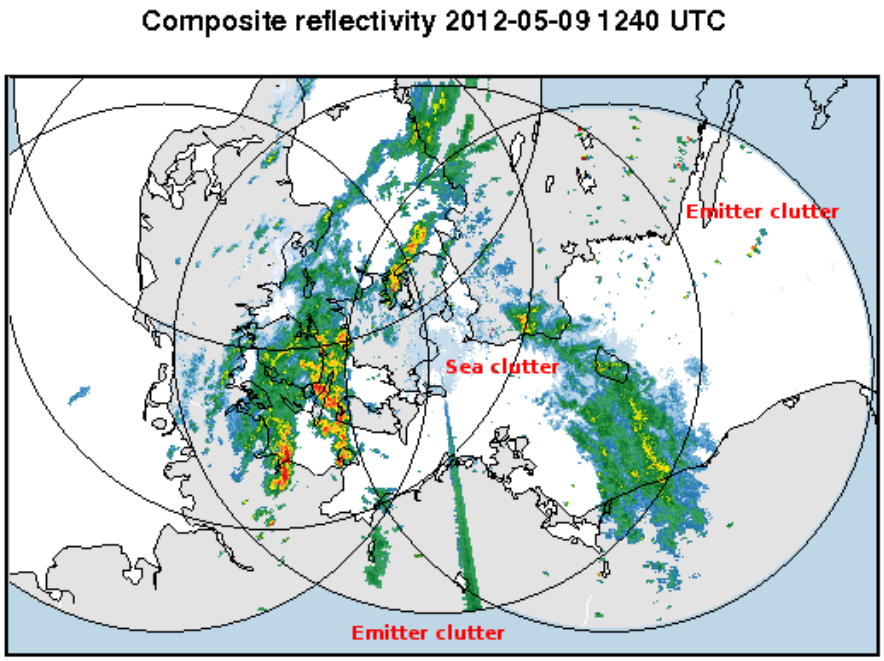
`New radars´:
Virring
Bornholm

New radars are socalled `dual –pol´

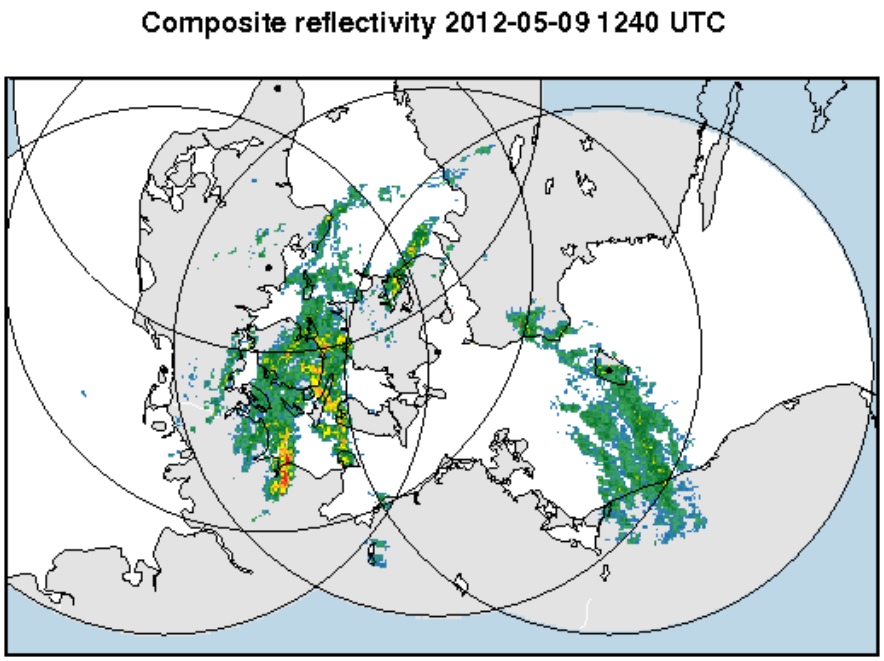
Notice that the radars are overlapping which can be used for calibration purposes



The importance of corrected radar data



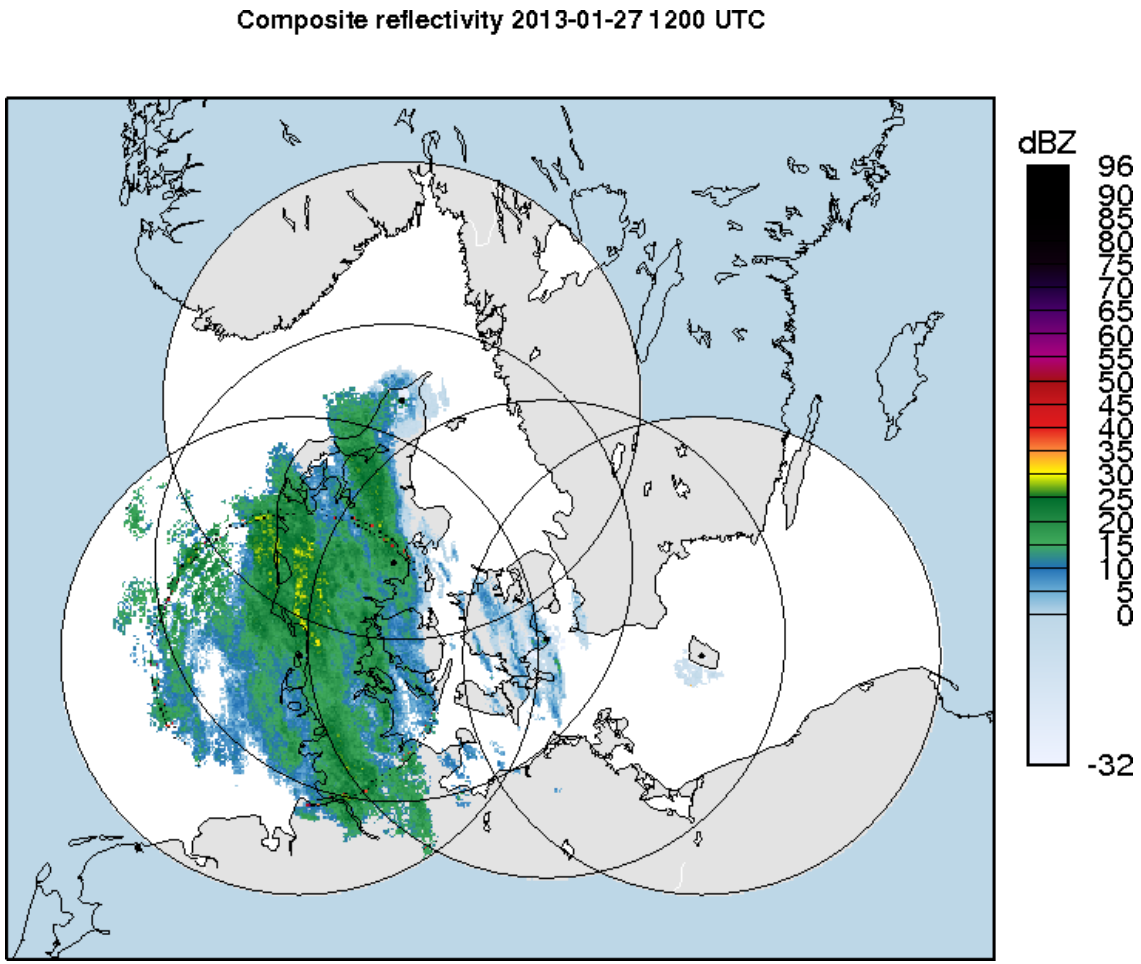
Unfiltered original pseudo-CAPPI composite
500 m pixel size, nearest radar



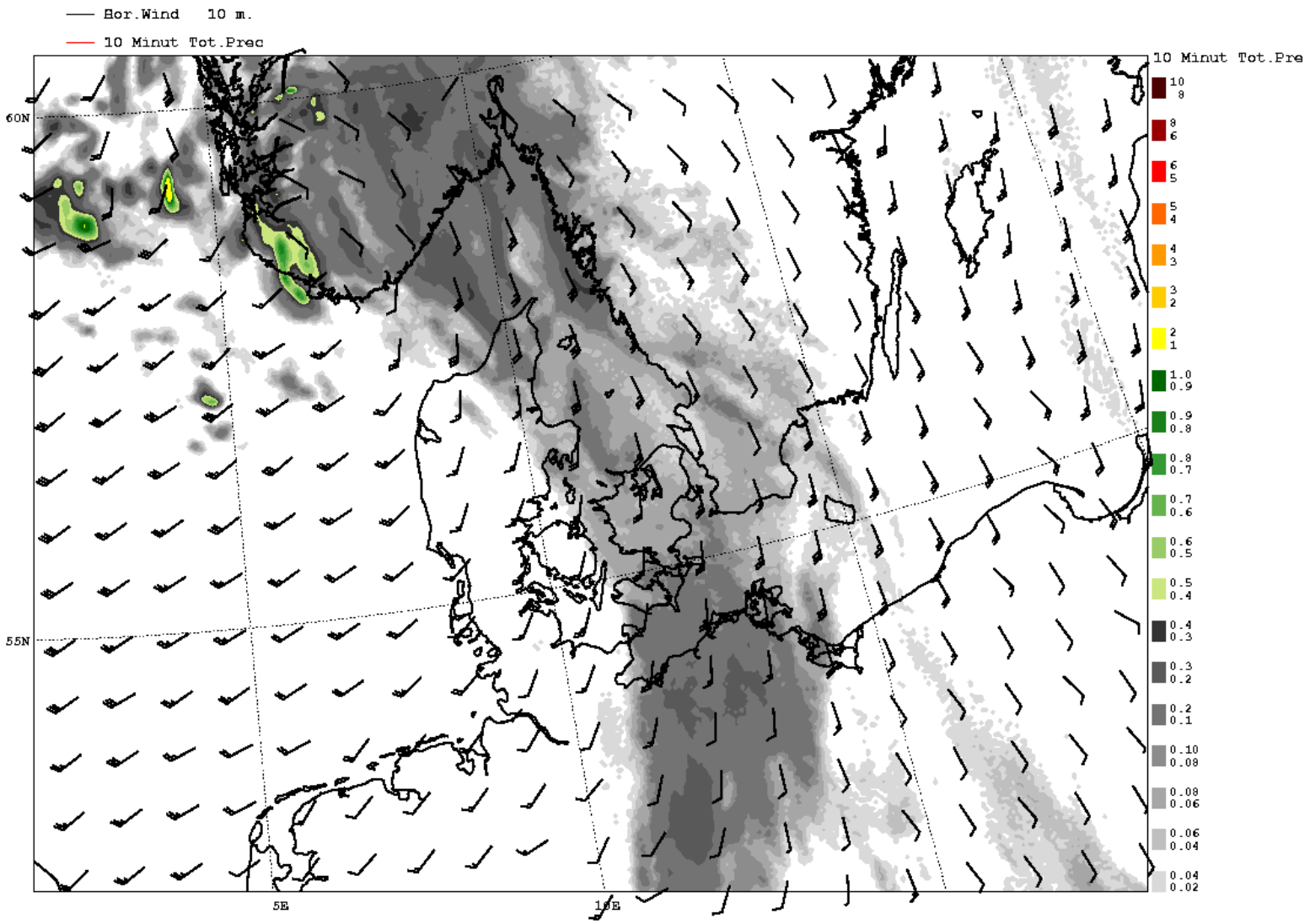
Filtered pseudo-CAPPI composite
2000 m pixel size, nearest radar

Version 1 for assimilation:
- emitter clutter filter
- correction of gain bias
- filtering out of reflectivities < 7dBZ (~ 0.1 mm/h)
- available in HDF5 file format

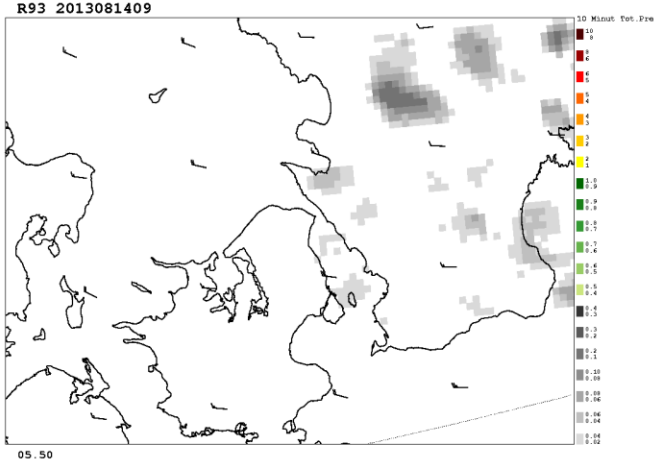
Assimilating partially erronious radar data `ring of fire´



Forecast involving ‘RING OF FIRE’



R93 2013081409



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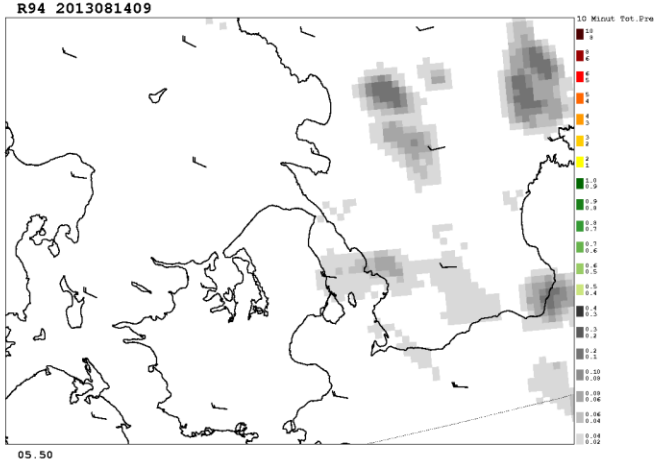
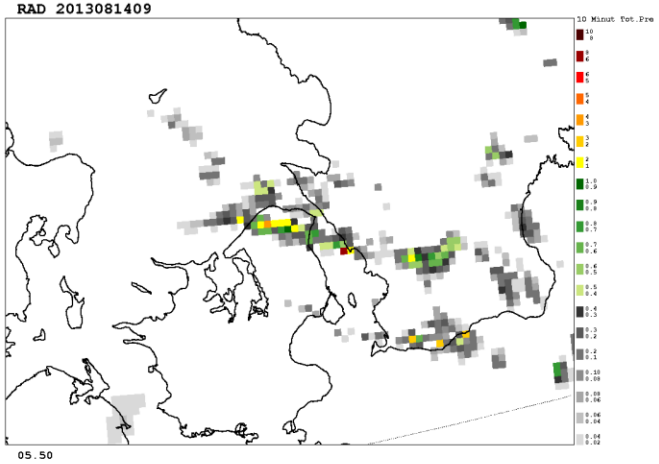
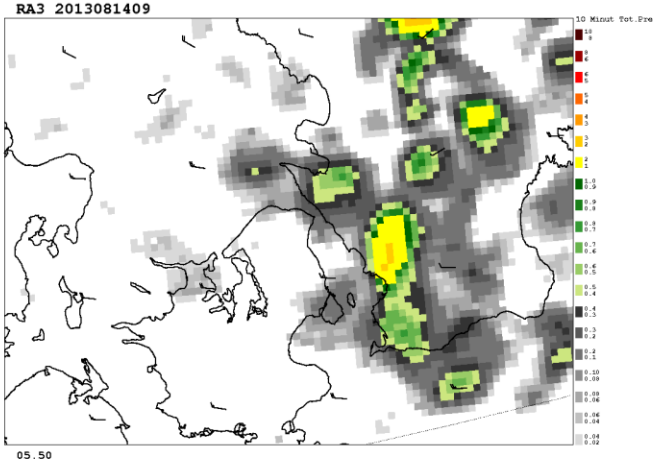


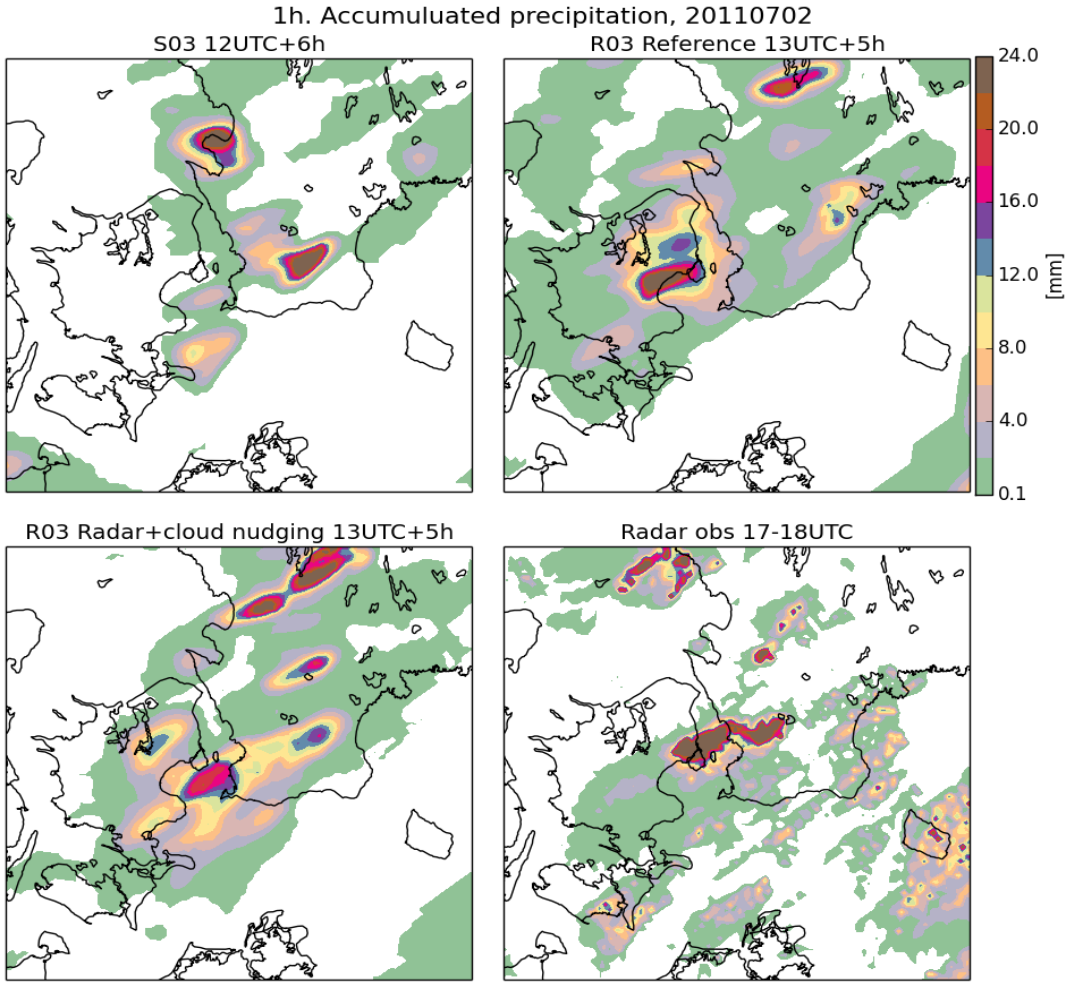
RAD 2013081409



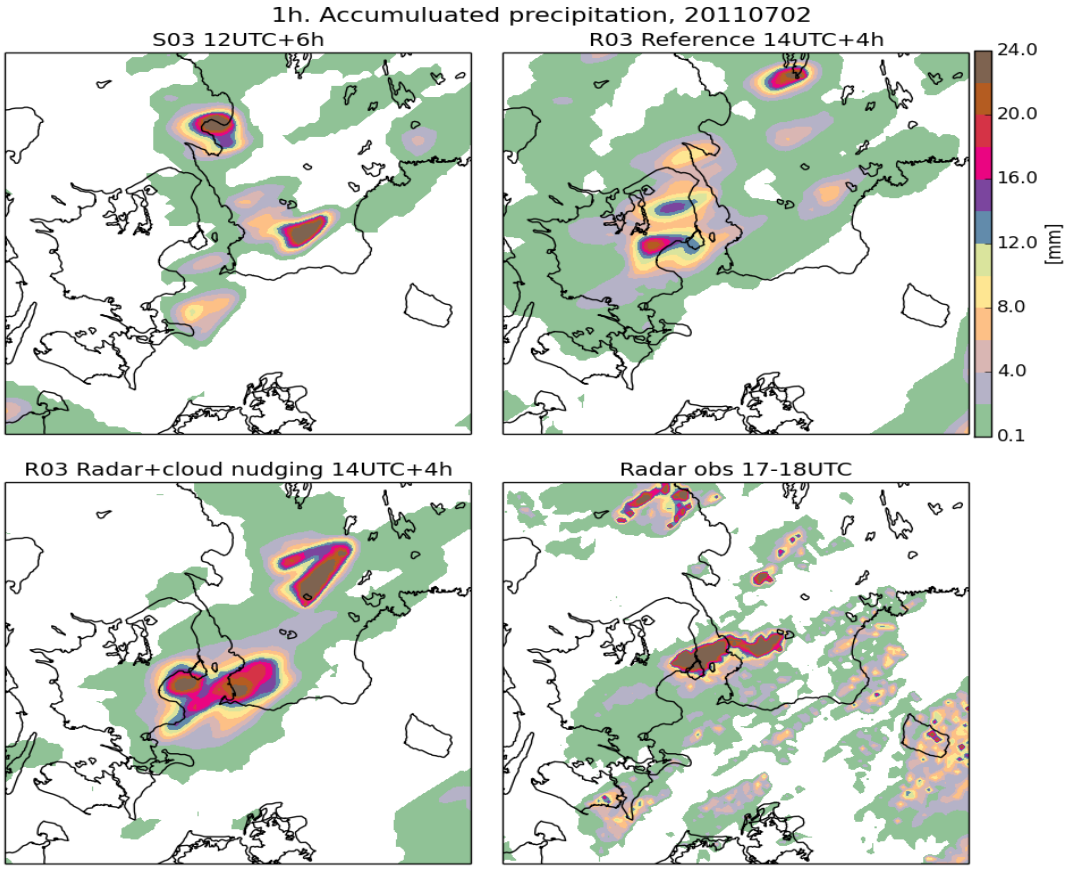
RA3 2013081409



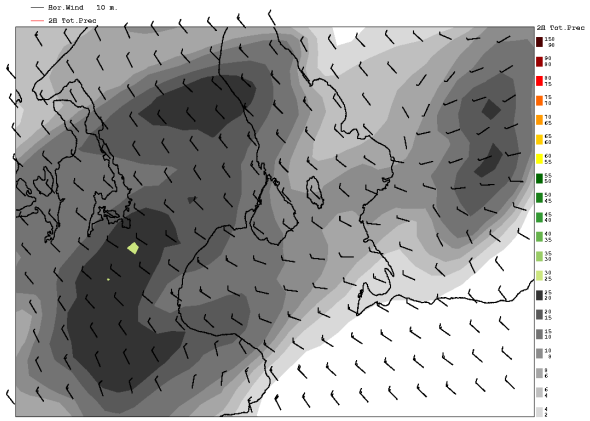
Flash flood in Copenhagen 2 July 2011 (1)



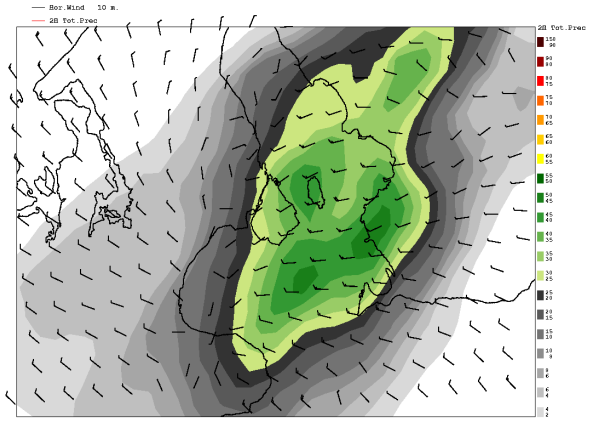
Flash flood in Copenhagen 2 July 2011 (2)



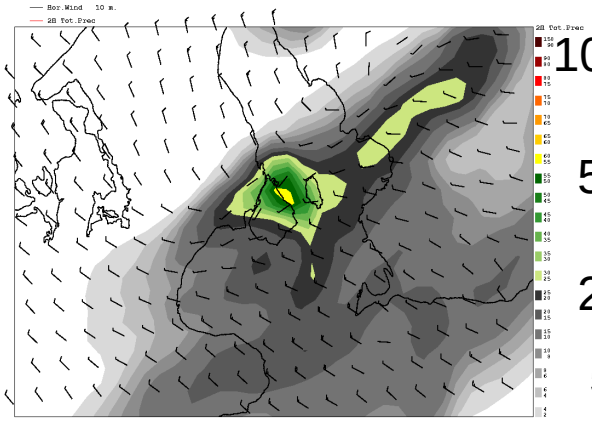
Rerun of 2/7-2011 15 UTC
4 hours forecast/assimilation 2 hours



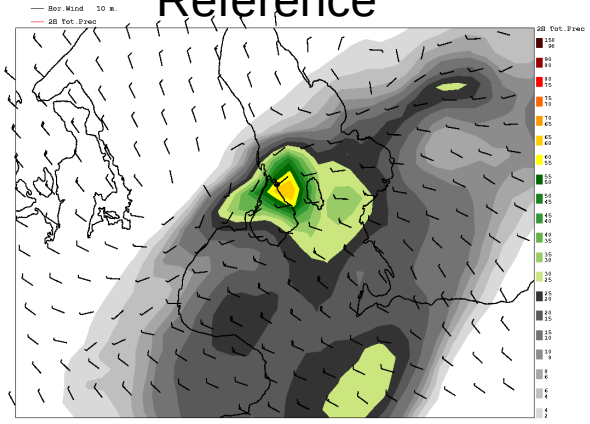
Reference



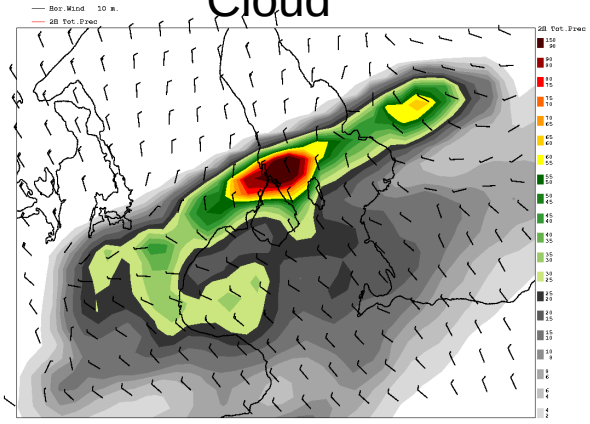
Cloud



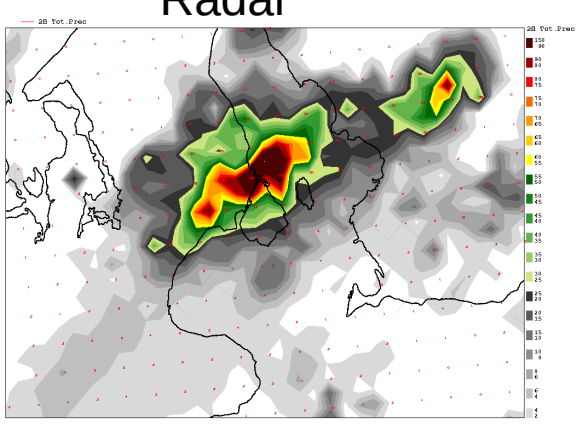
Radar



Cloud+Radar



Cloud+Radar+RFD



Obs

conclusions and outlook (1)

Conclusions

- The new assimilation of data from radar deduced precipitation is fast and numerically very stable for a period of almost a year
- The scheme adjusts quite well the model precipitation to radar-deduced precipitation during assimilation period
- Operational screening and correction of radar data not representing precipitation properly is essential
- Good experiences with rapid update compared to e.g. 6 hourly cycles (e.g. the severe Copenhagen flash flood was forecast hours before it occurred with rapid updates, but not with 6-hourly cycling)

conclusions and outlook (2)

Outlook

- Radar derived precipitation for verification purposes will be made operational by the end of 2013. New verification scores , e.g. fractions skill score will be used.
- Potential shortcomings of the current method for assimilating radar data will be cured as far as possible
- Is it wise to combine NWP with radar extrapolation methods in the short term, e.g nudging towards extrapolation for the first hour ?
- Investigate possibility to transfer new ideas to Harmonie system
- What is the potential of an ensemble of model runs for Nowcasting ?

THANKS FOR YOUR ATTENTION !