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Precipitation nowcasting at Finnish Meteorological Institute

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Finnish Meteorological Institute

Nowcasting tools at FMI

RADAR – Operational probabilistic ensemble nowcasting and research in object-oriented nowcasting with NON-METEOROLOGICAL EXTERNAL DATA

HIRLAM/HARMONIE – Operational deterministic models, seamless blending of ensembles (PEPS) with radar and with ECMWF ensembles

LIGHTNING LOCATION – R&D in lightning & rainfall analysis and nowcasting

LAPS – FMI operational meso-scale analysis. R&D: HARMONIE hot start with LAPS (see EUMETNET Nowcasting activity)

SATELLITE – Polar orbiting and stationary satellites, NWCSAF etc. (CRR but mostly clouds)

Note: Flood forecasting is not part of FMI's responsibility

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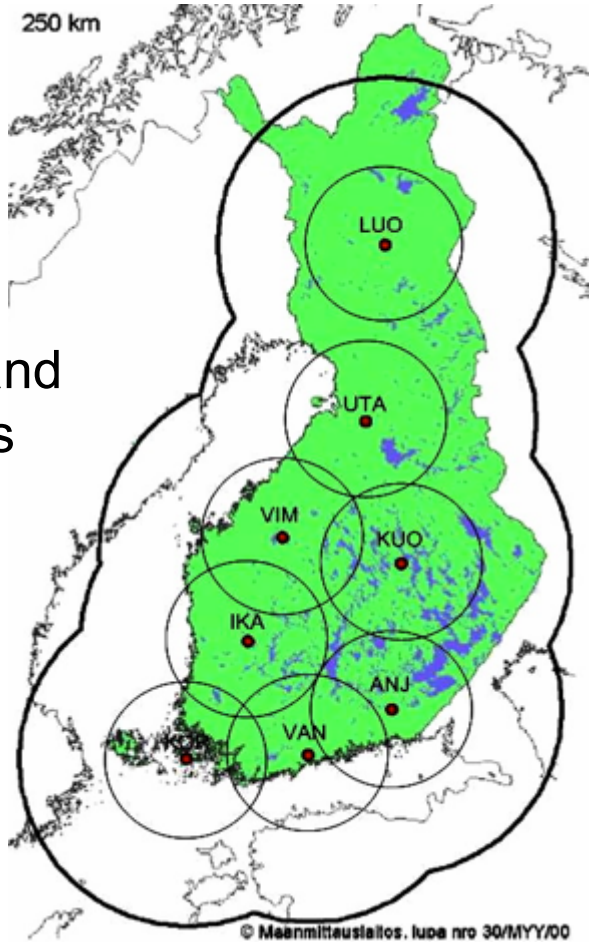
Radar-based nowcasting

8 C-band Doppler Radars (7 with dual polarization)

Data utilization rate 98.5 %
incl. maintenance and telecommunications

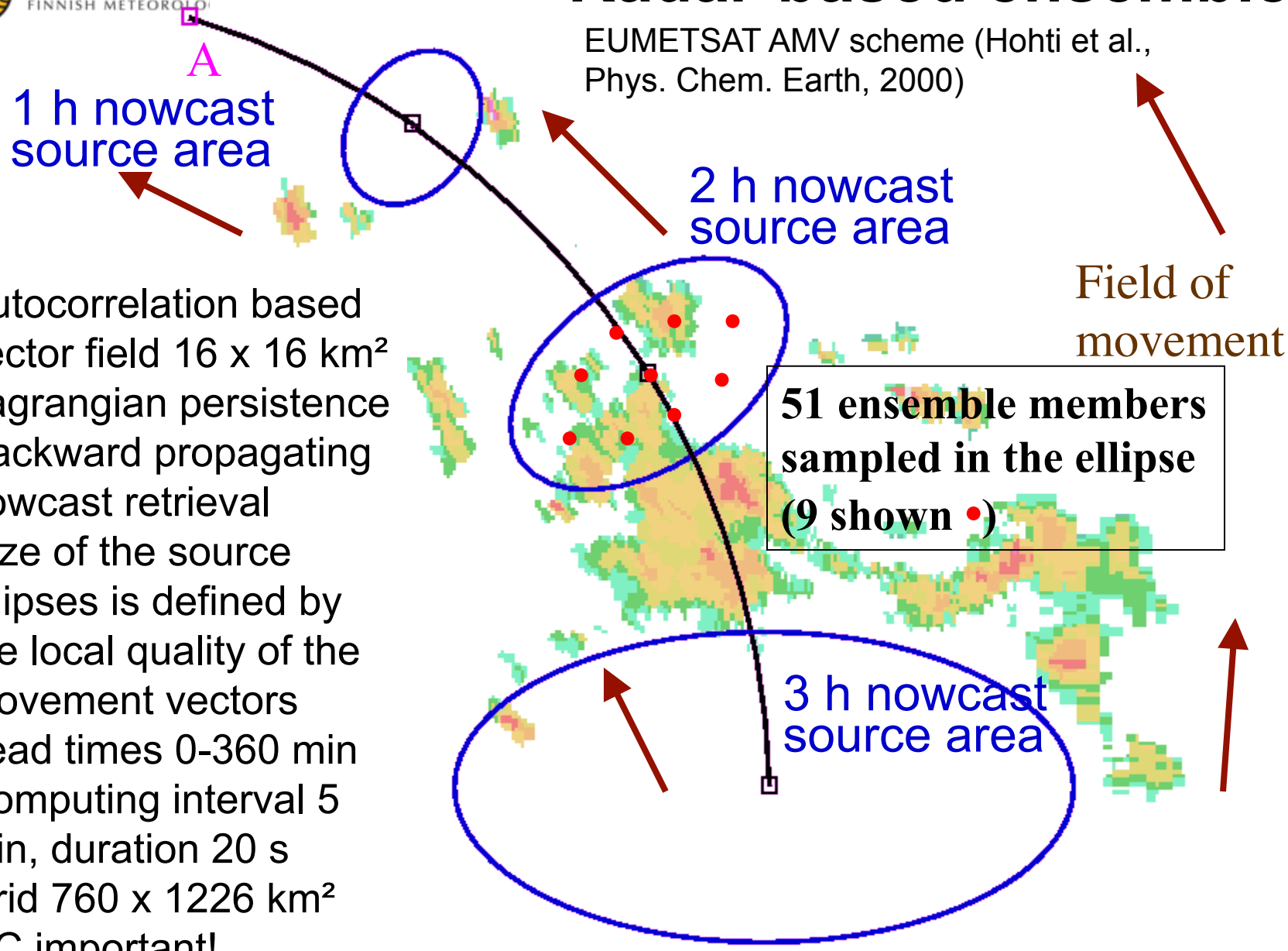
Nowcasting area: whole Finland with resolution 1 km².



Koistinen et. al., 2012: Probabilistic rainfall warning system with an interactive user interface. IAHS Publication 351, 394-399 (WRaH 2011 Special Issue).

Radar-based ensembles

EUMETSAT AMV scheme (Hohti et al., Phys. Chem. Earth, 2000)



- Autocorrelation based vector field 16 x 16 km²
- Lagrangian persistence
- Backward propagating nowcast retrieval
- Size of the source ellipses is defined by the local quality of the movement vectors
- Lead times 0-360 min
- Computing interval 5 min, duration 20 s
- Grid 760 x 1226 km²
- QC important!

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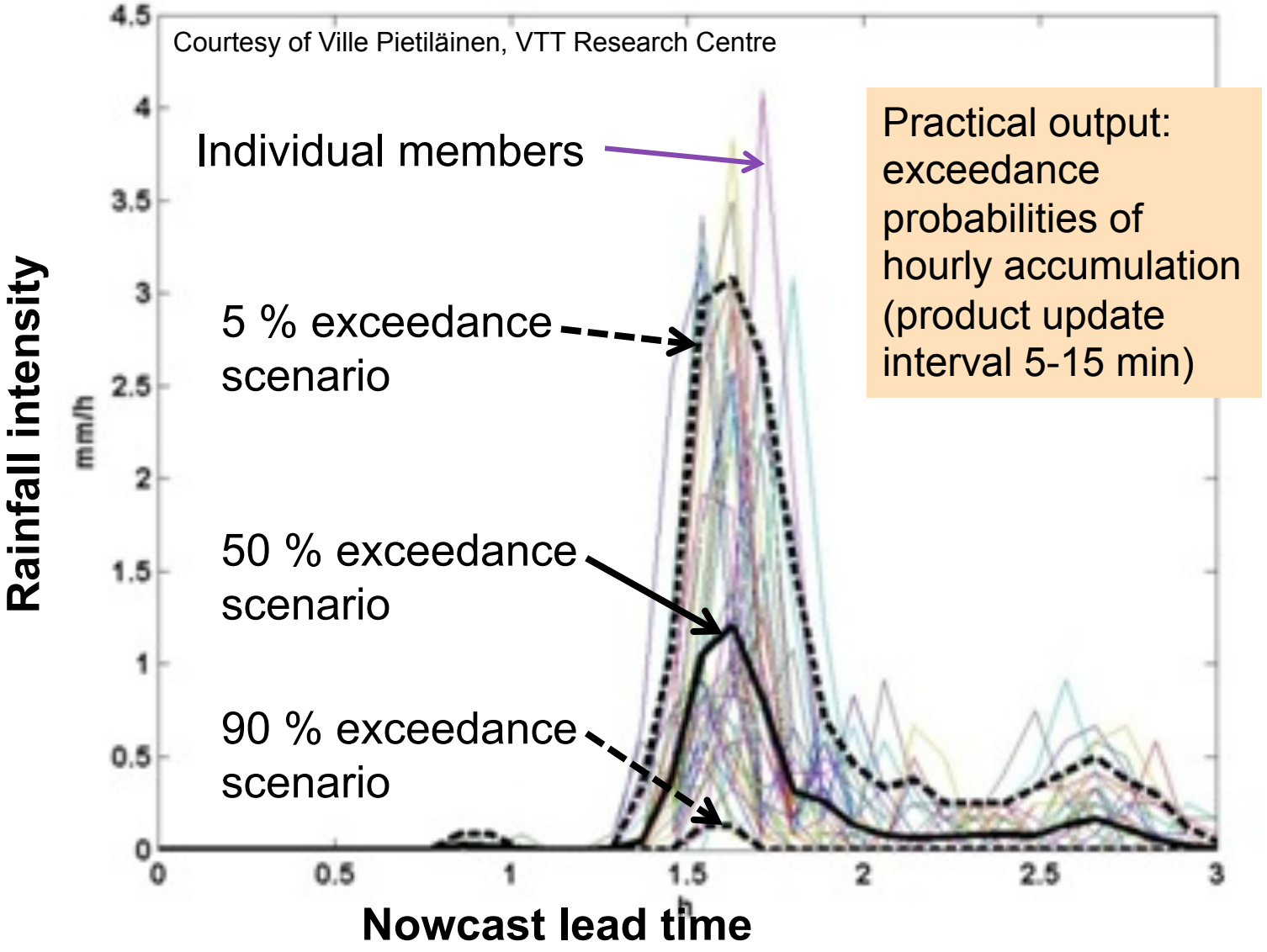
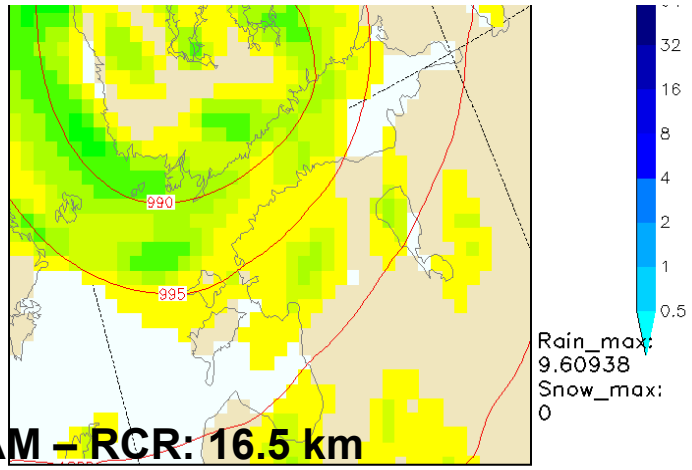
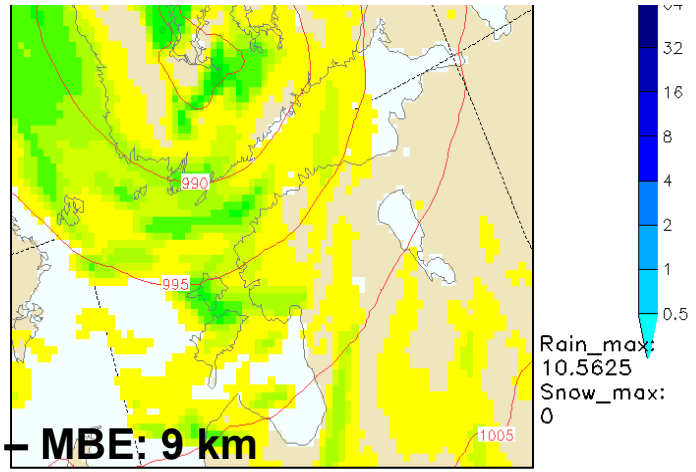
Exceedance probabilities for each location from ensembles



Numerical weather prediction (NWP) applied for 2-96 h forecasts

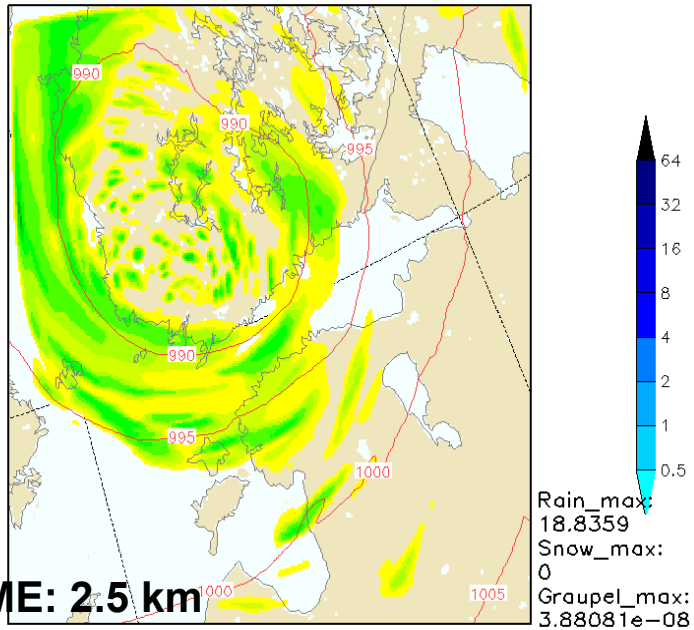


HIRLAM – RCR: 16.5 km



HIRLAM – MBE: 9 km

AROME 31JUL2007 00 UTC Forecast. Precipitation [mm 1h^{-1}]
31JUL2007 09:00 UTC (ARO,2.5km)



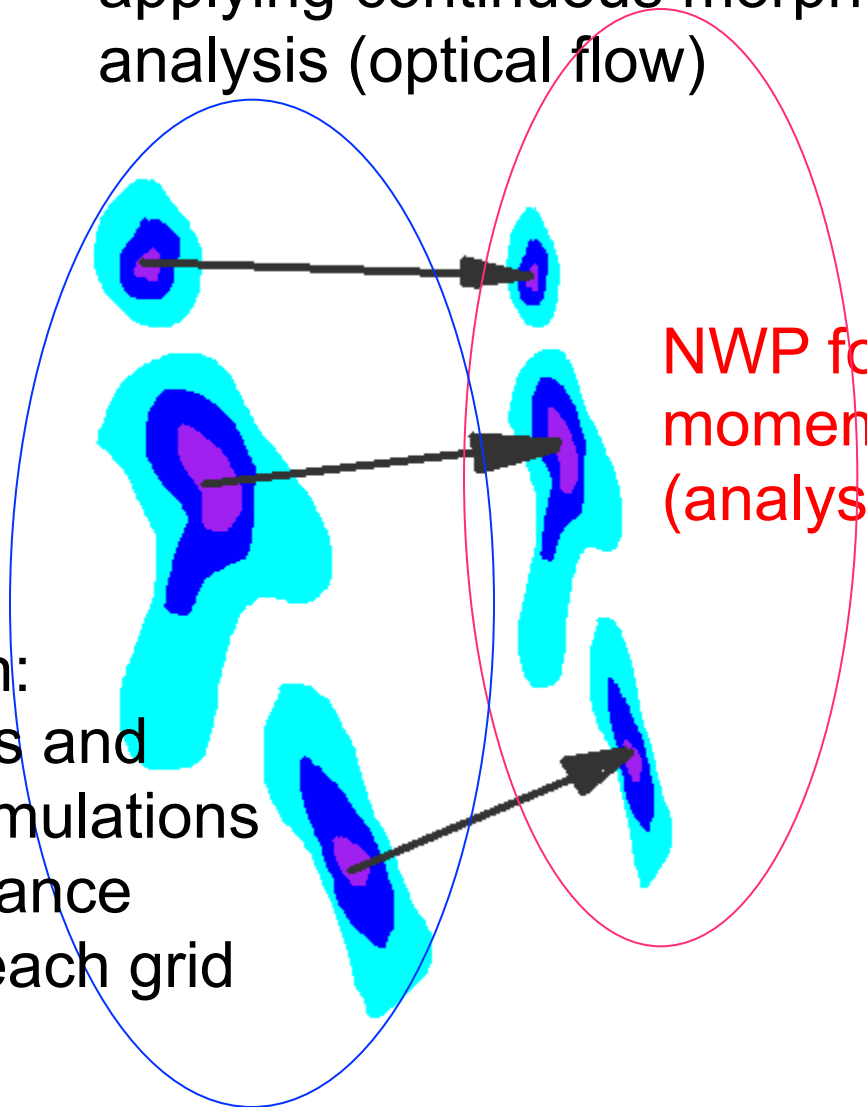
AROME: 2.5 km

- 51+51 ensemble members applied
- EPS (ECMWF) and PEPS (AROME & HIRLAM) methods applied (Theis et al. 2005)
- Limitations: Update cycles of NWP are too sparse (6-12 h) for nowcasting and often convective systems don't match the real ones in time and place.

Challenge: Blending of forecasts from various sources into one continuous ensemble

Example: Integration of radar and NWP by applying continuous morphing vector analysis (optical flow)

Radar based nowcast at +2h



NWP forecast at time moment +2h (analysis 3-9 h old!)

Working solution:
We omit patterns and blend only accumulations of equal exceedance probabilities at each grid point.

Seamless blending of ensembles

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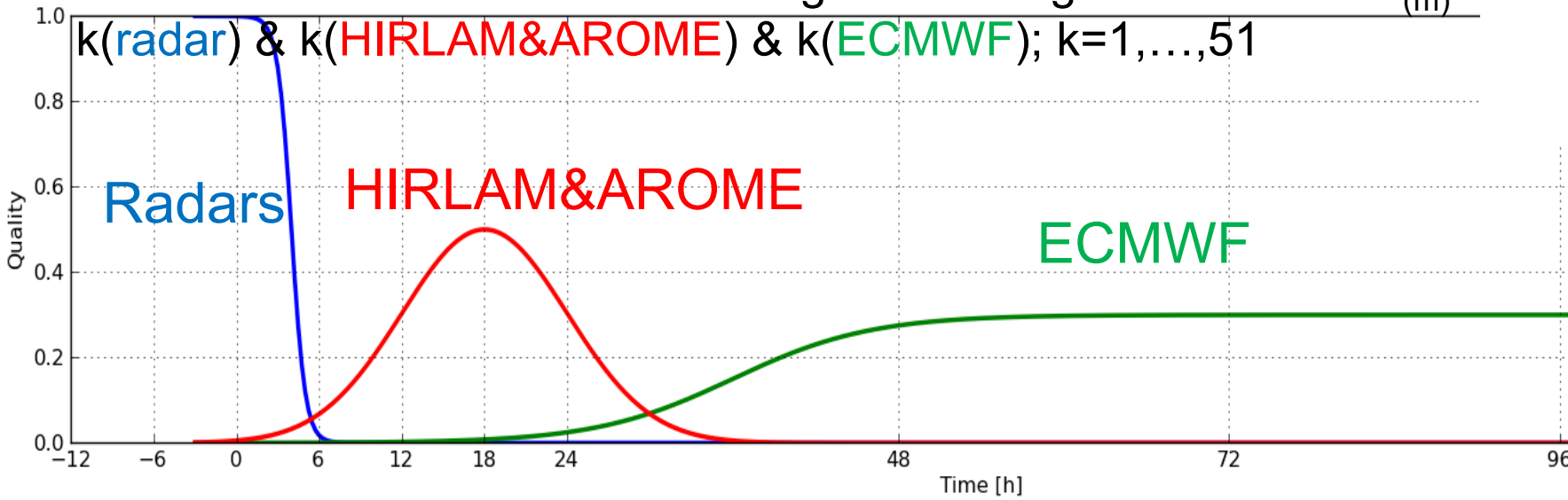
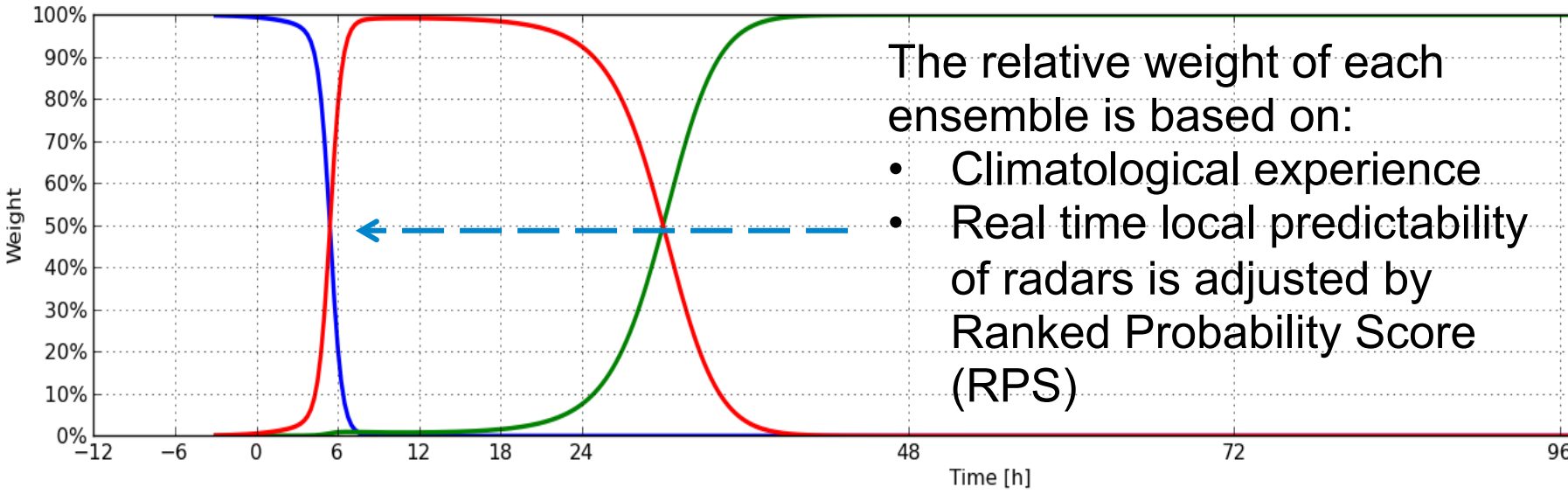
Blended member with rank k = weighted average of members $k_{(m)}$

k(radar) & k(HIRLAM&AROME) & k(ECMWF); k=1,…,51





The relative weight of each ensemble is based on:

- Climatological experience
- Real time local predictability of radars is adjusted by Ranked Probability Score (RPS)

Probabilistic forecast products

3 accumulation periods:

- 1 h
- 3 h
- 12 h
- Multiple lead times: 13-16, 14-17…

Each period is attached with 4 rainfall thresholds:

- Weak or any rain (whose complement is fair weather)
- Moderate
- Heavy (>7, >10 and >19 mm)
- Very heavy (return period 5 y)

Exceedance probabilities are computed for each threshold and period.

Examples of exceedance probability data

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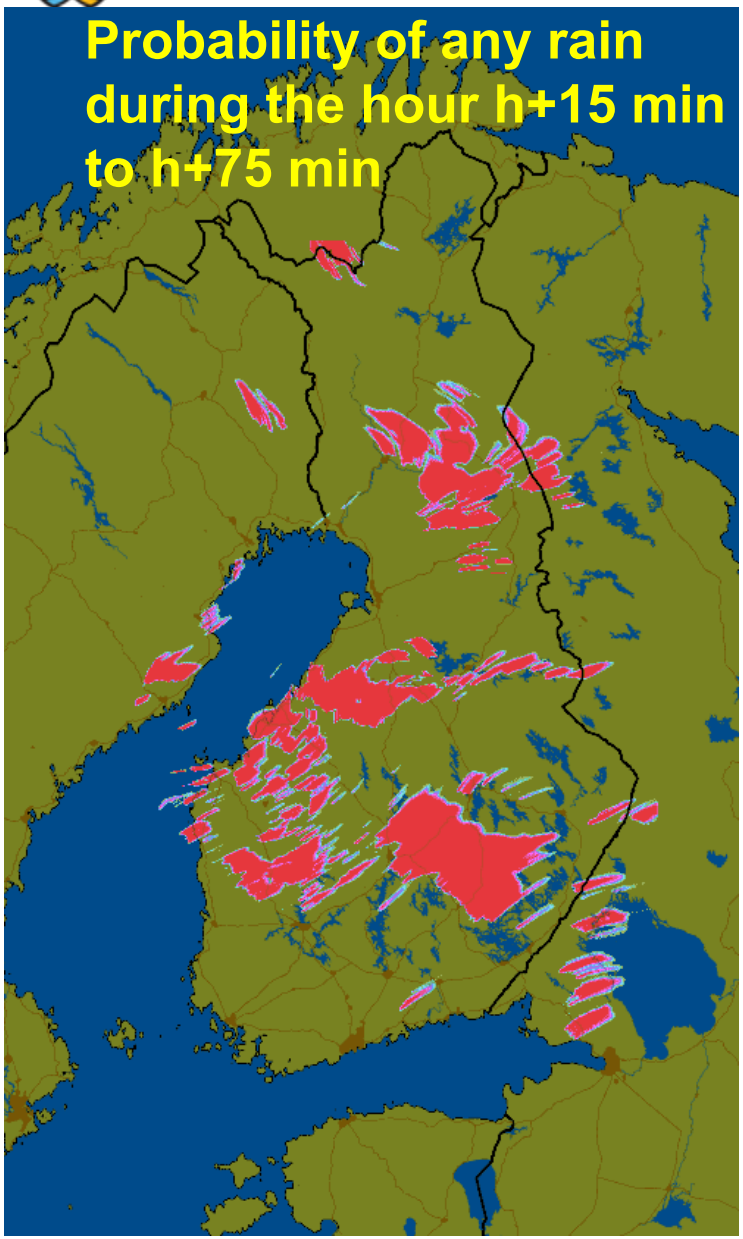

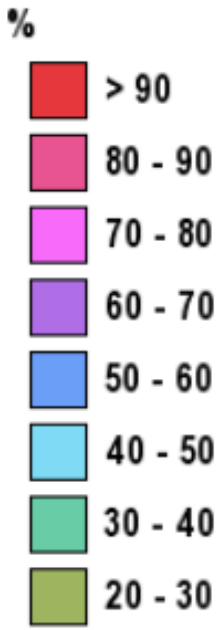

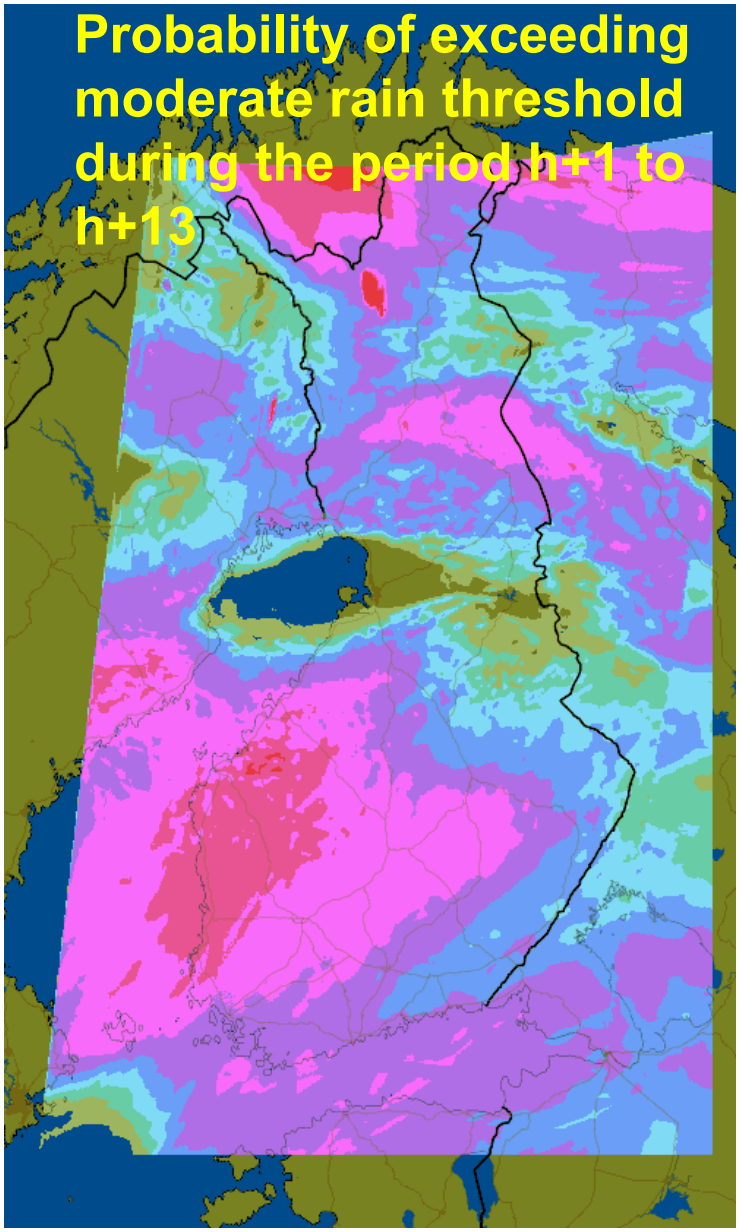

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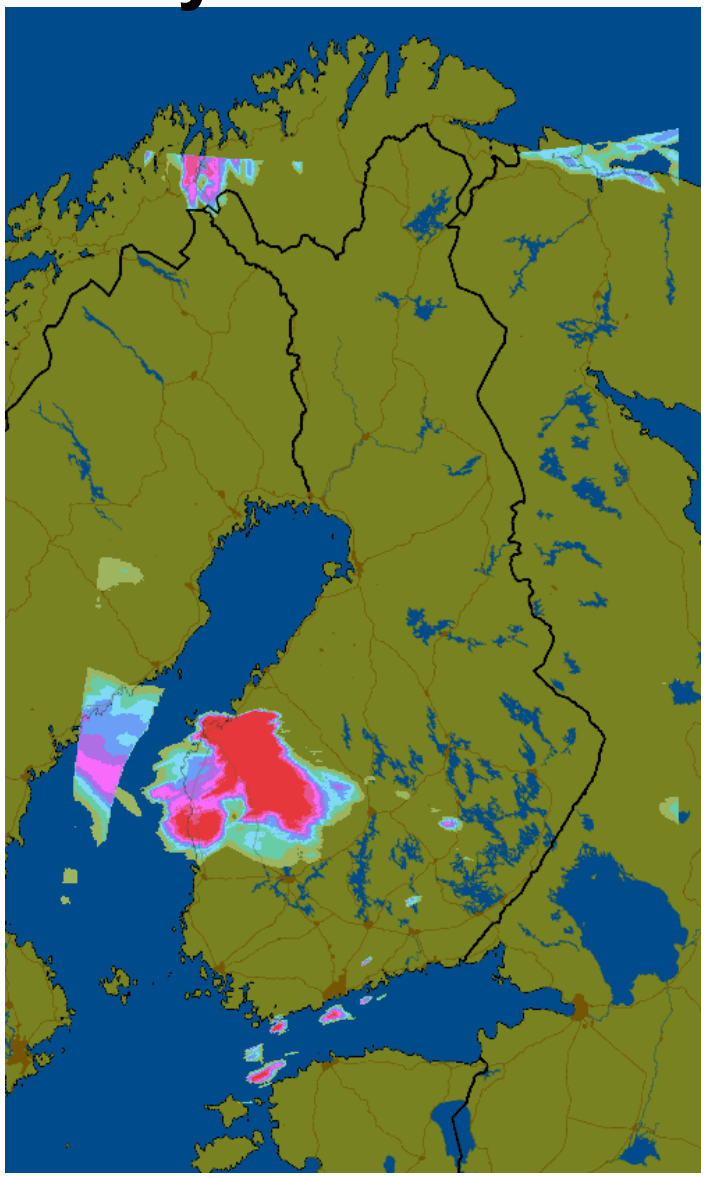
Meteorologists use forecasts in heavy rain and snowfall warnings

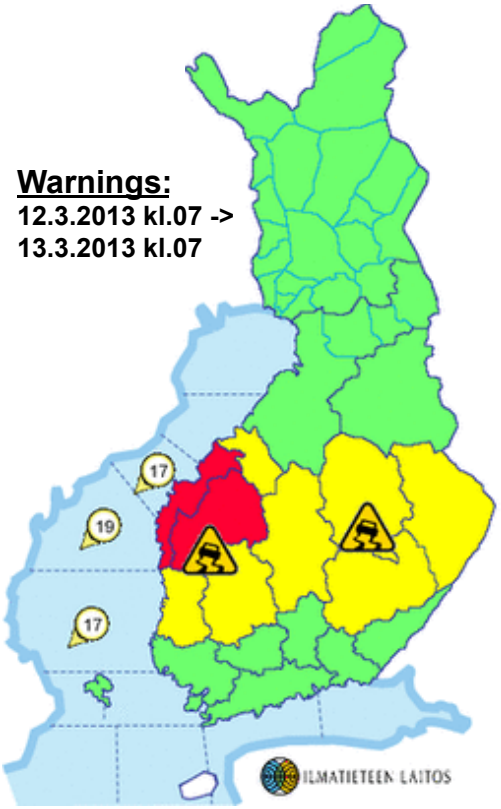
An example on 12 Mar 2013, issued at 9:00 local time

Animation of forecasted probability of precipitation:

- Forecast 24 hours
- In this case snowfall!



National warning is input to MeteoAlarm



Heavy rainfall alert service for any user

Interactive SMS user interface

- Ordering (1400 customers in 2012)
- Receiving alert messages (á 30 or 60 c)

Selections

Large areas should not be used

- Location (~~city~~, village, suburb)
- On-off switch any time
- Two class thresholds (any rain, heavy rain)

Not selectable

- Accumulation period (now 1 h, 3 h and 12 h combined)
- Threshold amount (e.g. 1 mm or 62 mm)
- Number of alerts (max 5/day)
- Dissemination threshold for exceedance probability (e.g. small, moderate, large or 75 %) – now fixed at **50 %**

Example message:
Weak rain at suburb Leppävaara will start at 18:15. The probability of rain is 60 %.
(radar map available from an other application)

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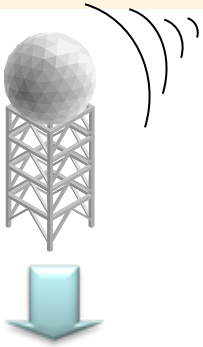
Professional application:

Influent management at Helsinki WWTP

Three areal 1 h nowcast scenarios: probabilities 5 %, 50 %, 90 %



Objectives

- **Alarming of predicted influent increase (capacity problems possible in extreme cases)**
- **Bypass flow minimization (environment risk)**
- **Operative actions to optimize influent tunnel volume (pumping)**

Rainfall-Runoff model
1 mm ~ 25 000 m³

Storm water inflow forecast

Decision support centre

Treatment capacity and process condition

Water level

Total influent
200 000 – 800 000 m³/day

Flow adjustment

Wastewater influent

Supply tunnel

Pumping

Viikinmäki WWTP

Heinonen et al., 2013: Water Sci. Technol., 68, 499-505.

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R&D Projects funded by EU

Hazard Assessment based on Rainfall European Nowcasts (HAREN, 2011-13, see http://www.crahi.upc.edu/
&
European Demonstration of a rainfall and lightning induced Hazard Identification nowcasting Tool (EDHIT, 2014-15)

European-wide rainfall nowcasting projects

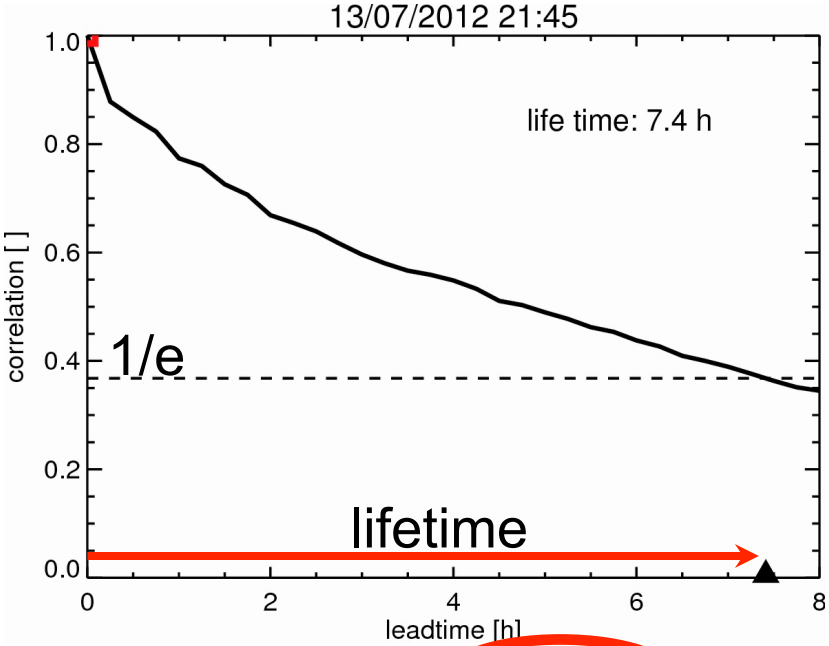
- Partners FMI, MoI (Finland), CRAHI (Spain), ZAMG (Austria), EFAS/SMHI (Sweden)
- Funded by EU Civil Protection

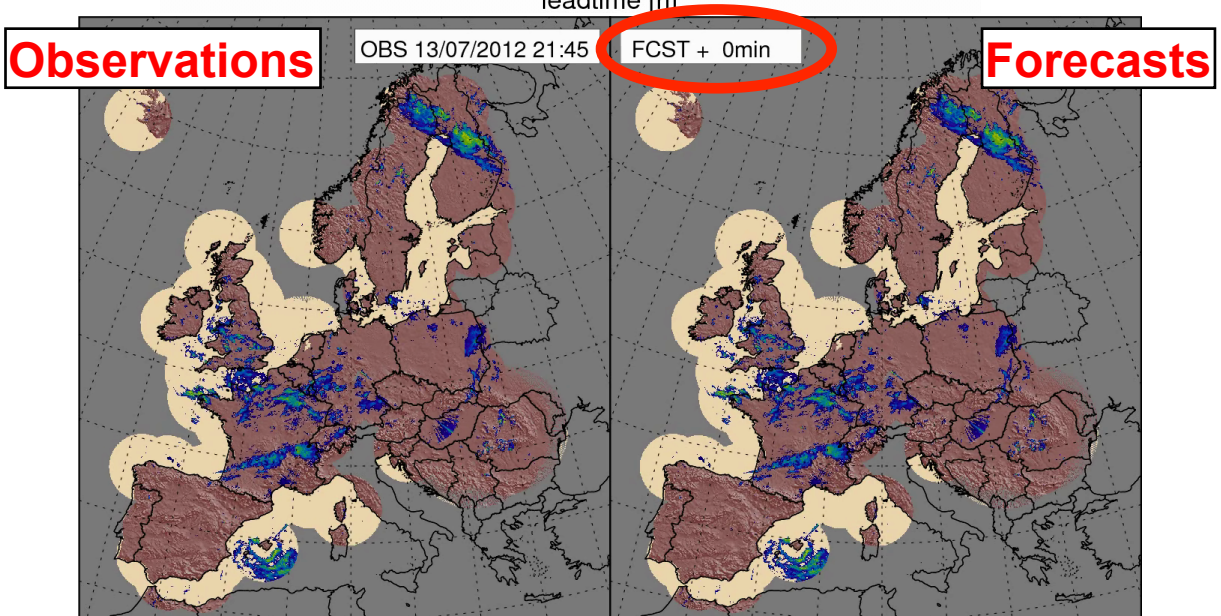
Both probabilistic and deterministic demonstration nowcasts developed

- EUMETNET/OPERA radar data has a major role (AMV & COTREC schemes, Germann and Zawadzki, 2004) – provided that we will obtain a licence!
- Additionally, NWP-based PEPS forecasts, developed at FMI, are applied
- Lead time 0-6 hours
- Pilot end users: National rescue services and weather services, MeteoAlarm, EFAS

HAREN Nowcasting evaluation

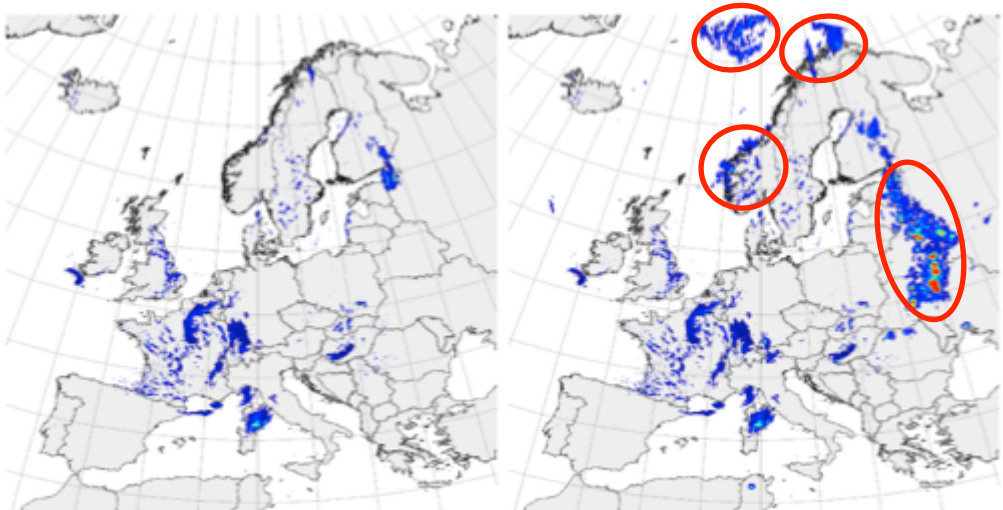
13 July 2012 21:45 UTC





EDHIT Task B.2: Improving heavy rainfall nowcasting using lightning nowcasts

- **The multi-sensor approach, demonstrated in HAREN, will be implemented for real-time production**
- **The method supplements European-wide radar information with lightning data (Vaisala GLD 360)**
  - The primary motivation is to obtain lightning nowcasts and a more complete and robust picture of the intense rainfall events
- **Outside radar coverage, precipitation is estimated using a method based on lightning density maps**



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Radar based object oriented convective storm tracking:

A well-established tool for severe weather nowcasting

- Detection of storm objects from weather radar images

- Organizing the objects in consecutive radar images into tracks

Nowcasting is typically based on the extrapolation of the storms, using the history of the storms

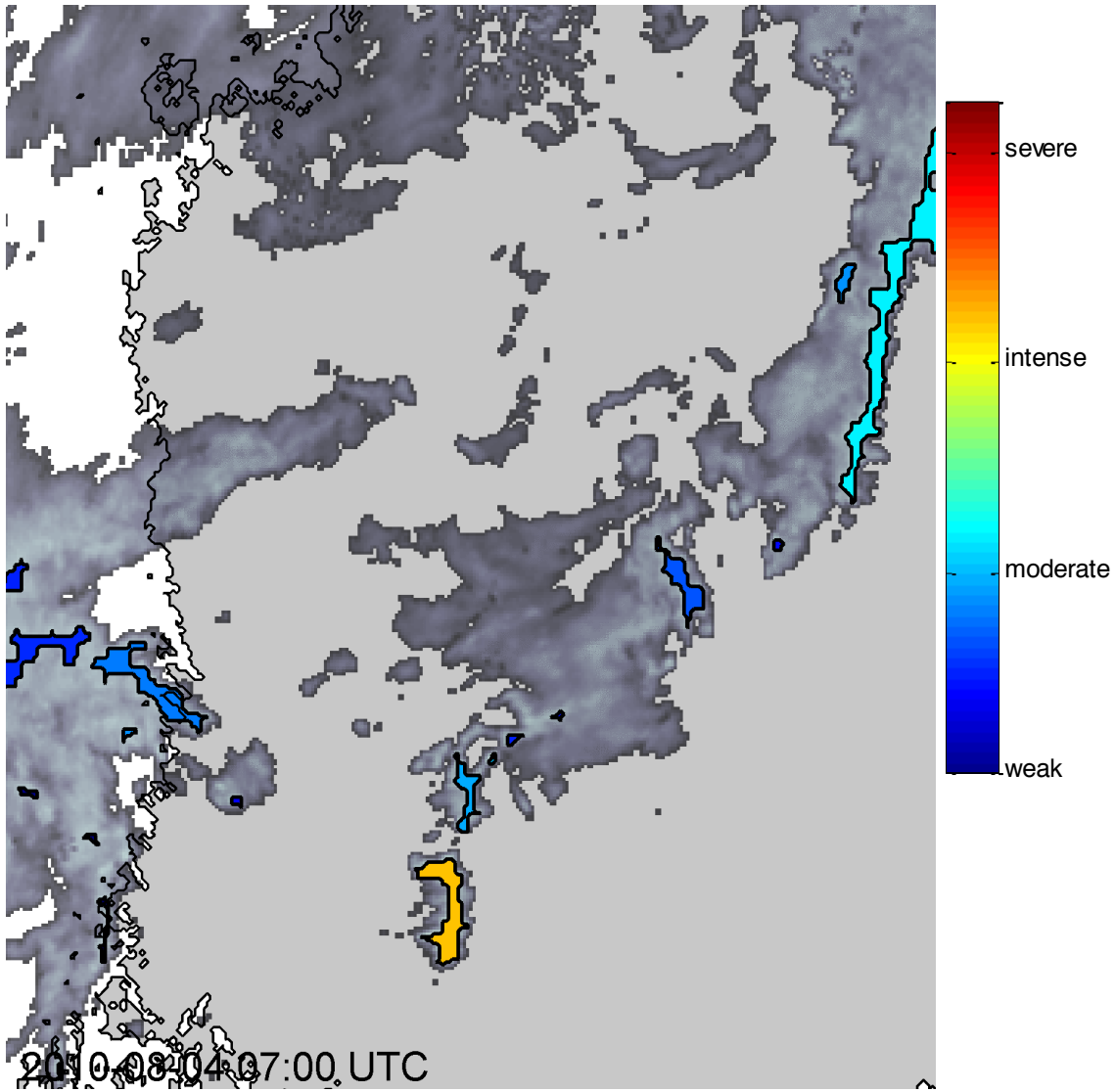


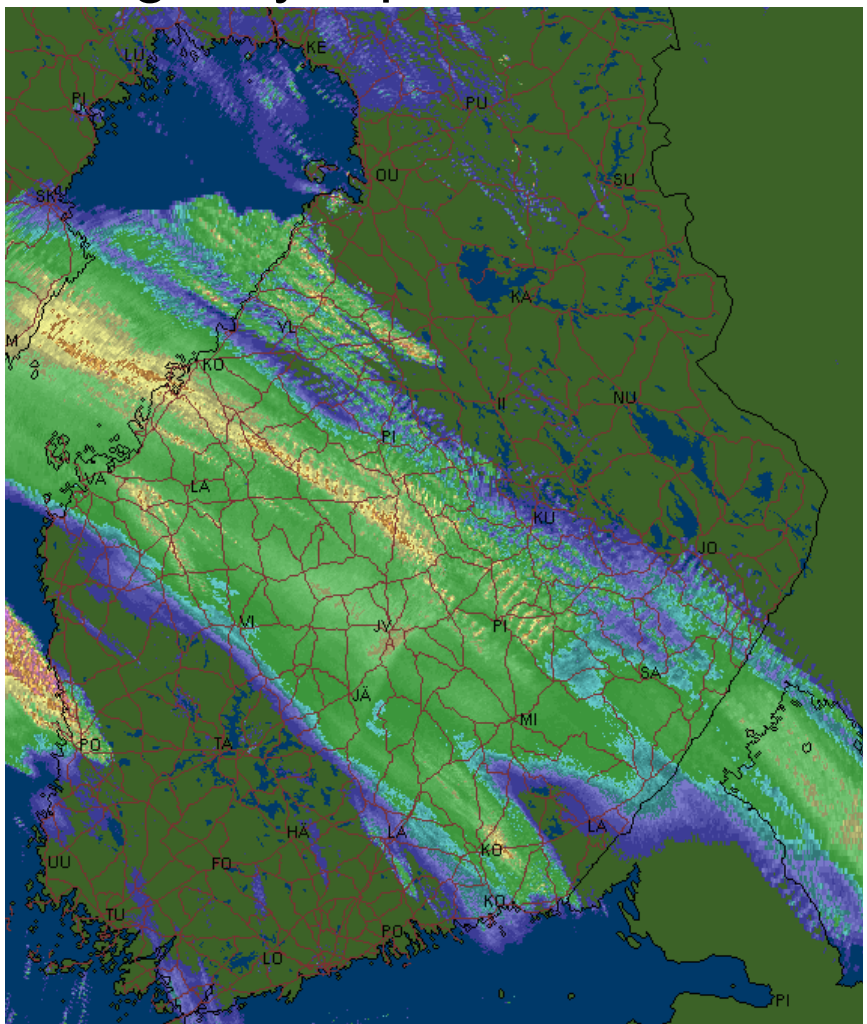
Figure to right:

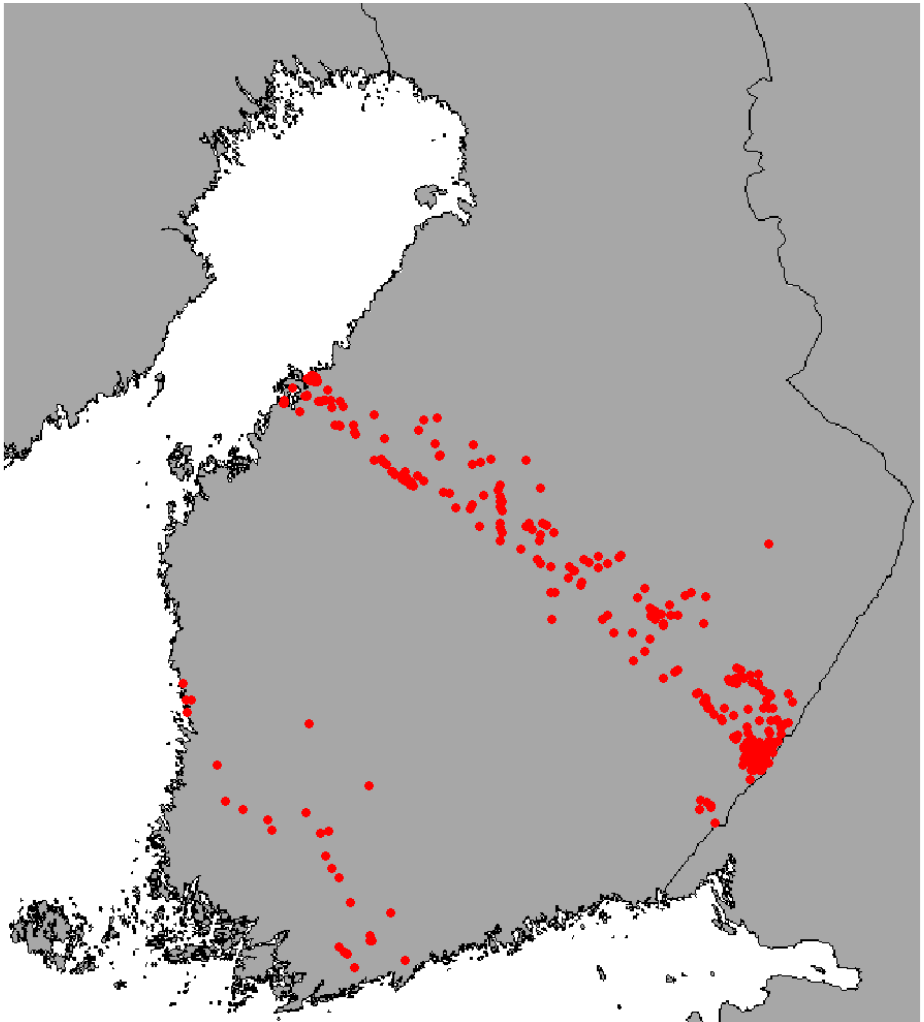
Index based intensity, combining radar and lightning information

→ Storm location +30 min

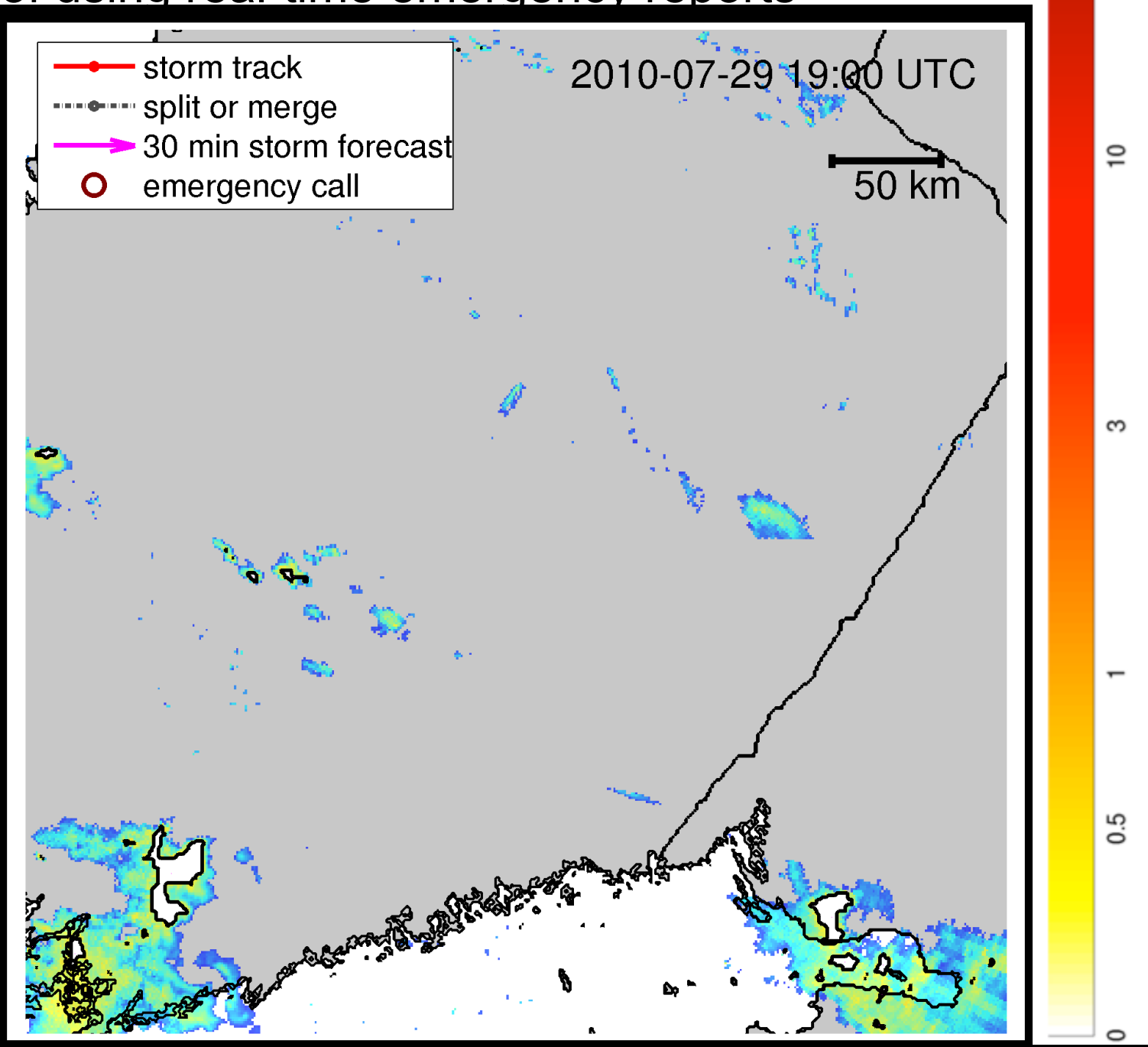
EDHIT Task A.3: Enhancing European-wide hazard identification using rescue reports and trusted spotter networks (e.g., ESWD)

- MCS on 29.7.2010: 6h radar based rainfall accumulation vs. emergency report data





Example of using real-time emergency reports



Future risk management process

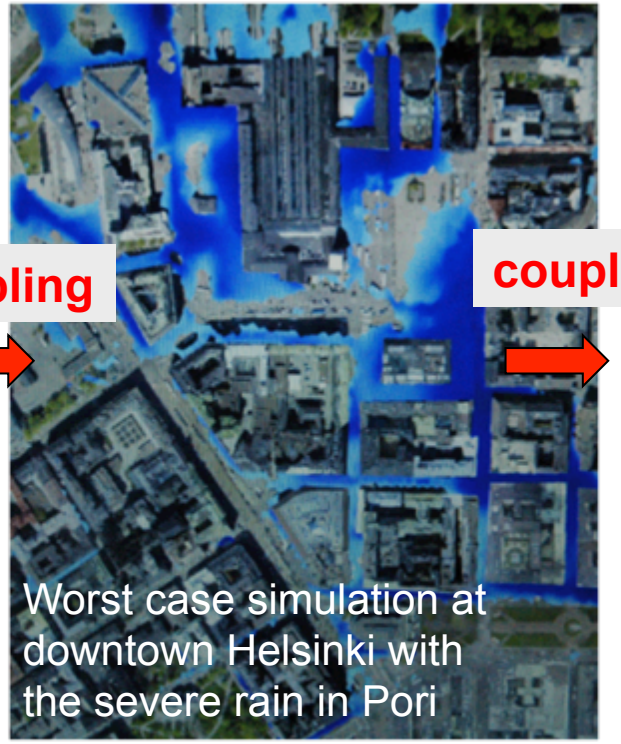
Overflow risk management and automatic alarming for real estates and rescue personnel was recently tested in Helsinki city center in a pilot study. Three process phases needed in COUPLED storm water nowcasting:

1. Rainfall ensembles

2. Water flow ensembles

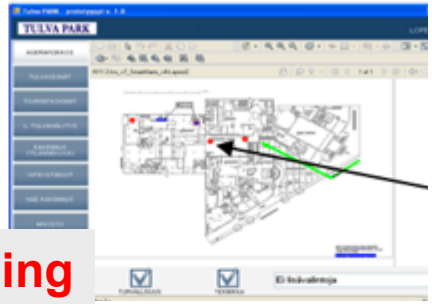
3. Event monitoring, alert and civil protection systems

coupling



Worst case simulation at downtown Helsinki with the severe rain in Pori

coupling



”Traffic light” flood risk monitoring & forecasts at critical points

Risks in real estate scale (upper)
Risks in city scale (lower)

”Traffic light” flood risk monitoring & forecasts at critical points

Still lot to do in a ”smart city” as only the process step 1 is quasi-operational!

Conclusions

- Seamless probabilistic forecasts have a great potential in the risk management of extreme rainfall.
- Coupling of rainfall ensembles with hydraulic & hydrologic models, high impact objects and, finally, with risk estimation will give even better tools for civil protection.
- Automatic alerts for each grid point and user is a challenge for the traditional, regional warning practices of NWSs (legislation, insurances, role of meteorologists) and for EUMETNET.
- HAREN & EDHIT: Pilot R&D projects for European radar and NWP based probabilistic precipitation and lightning nowcasts.
- Since 2013 FMI has opened the radar data (Inspire Directive).