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Probabilistic seamless extreme rainfall forecasting system for lead times 1-120 hours

Jarmo Koistinen[(1)], Harri Hohti[(1)], Janne Kauhanen[(1)], Juha Kilpinen[(1)], Pertti Nurmi[(1)], Pekka Rossi[(1)], Miikka Jokelainen[(2)], Mari Heinonen[(2)], Tommi Fred[(2)], and Dmitri Moisseev[(3)]

[(1)] Finnish Meteorological Institute (FMI)

[(2)] Helsinki Region's Environmental Services Authority HSY, Water management, Wastewater treatment

[(3)] University of Helsinki

Motivation: The human society will be increasingly sensitive to impacts of extreme weather and climate

Thunderstorm rain in Pori:

~120 mm in 3 hours
damage 15-20 M€

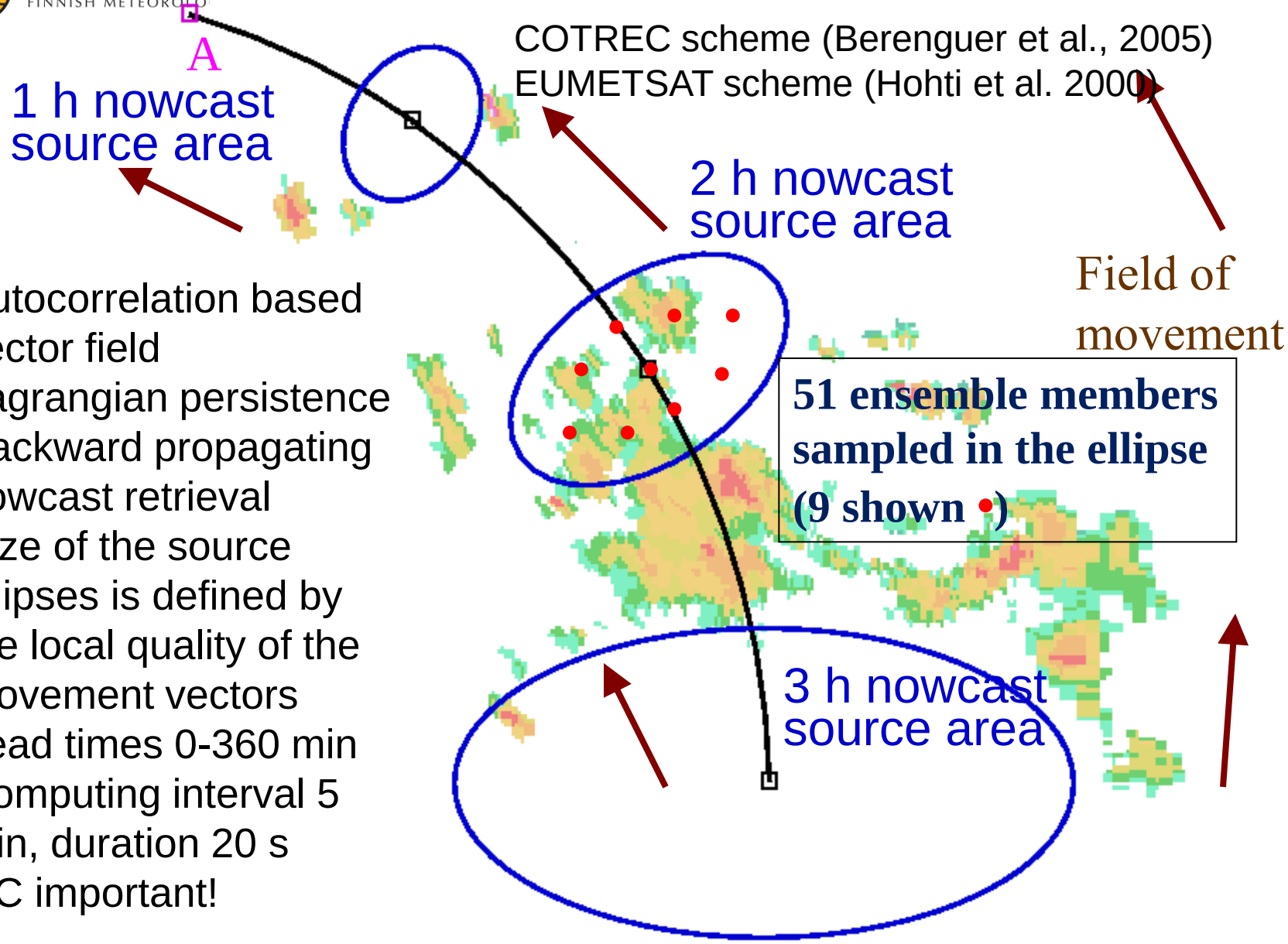
Underground flooding in Helsinki

Forecast lead times 1-120 h are not a key reserach area in BE
- but it is the main time scale of practical risk management actions!

Economic risk of a future weather event =
{probability of the event} x
{expected losses induced by the event}
Example: 0.01 (1 %) x 1000 M€ = 1 (100 %) x 10 M€.
Probabilities can be obtained by ensemble prediction systems (EPS).

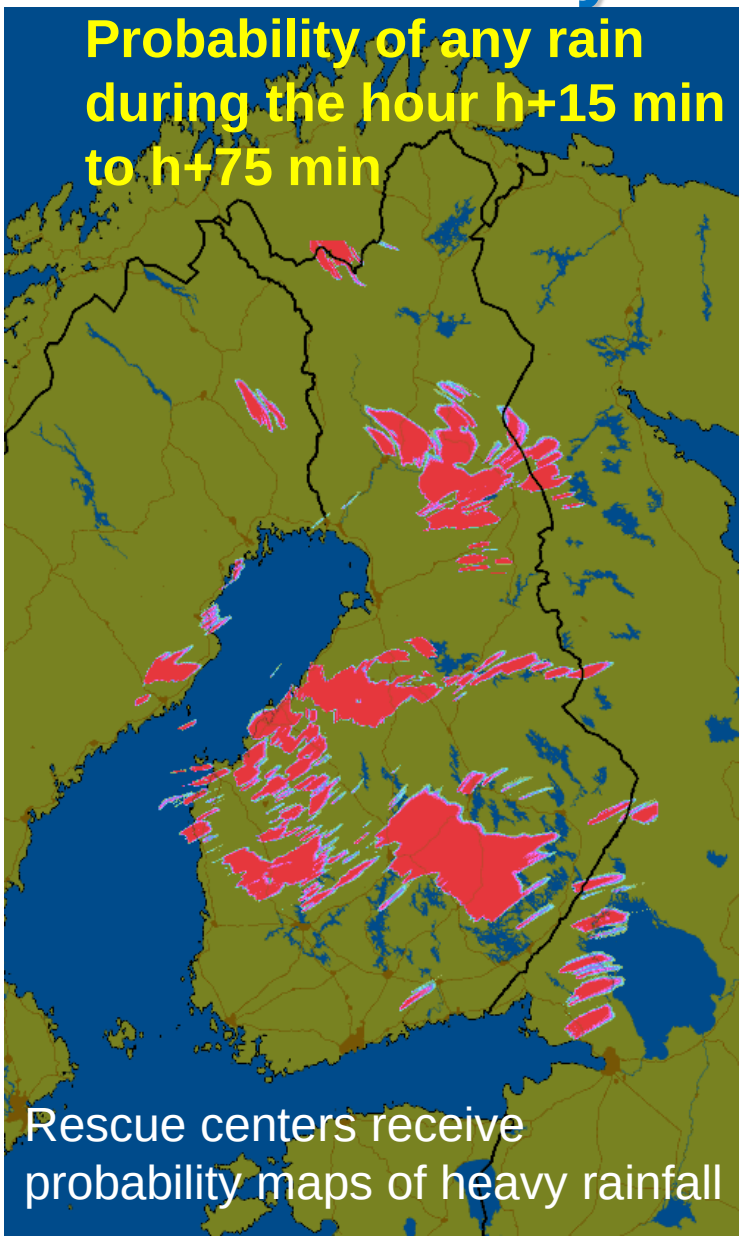
Radar based ensembles

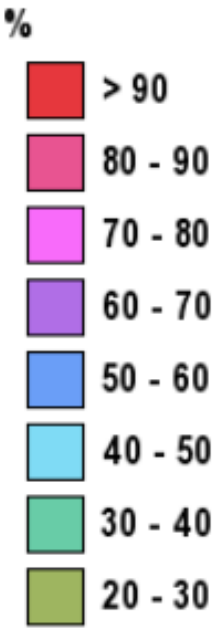
COTREC scheme (Berenguer et al., 2005)
EUMETSAT scheme (Hohti et al. 2000)



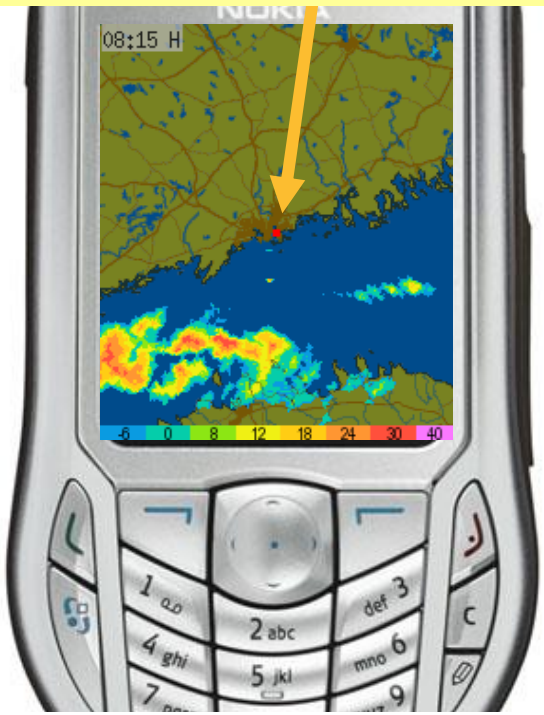
- Autocorrelation based vector field
- Lagrangian persistence
- Backward propagating nowcast retrieval
- Size of the source ellipses is defined by the local quality of the movement vectors
- Lead times 0-360 min
- Computing interval 5 min, duration 20 s
- QC important!

Probabilistic radar-based nowcasts disseminated from FMI by internet and SMS messages





Example SMS message: Weak rain at Helsinki city center during 08:45 – 09:45. The probability of rain is 57 %. (service available for any user)



Quasi operational interactive service at FMI

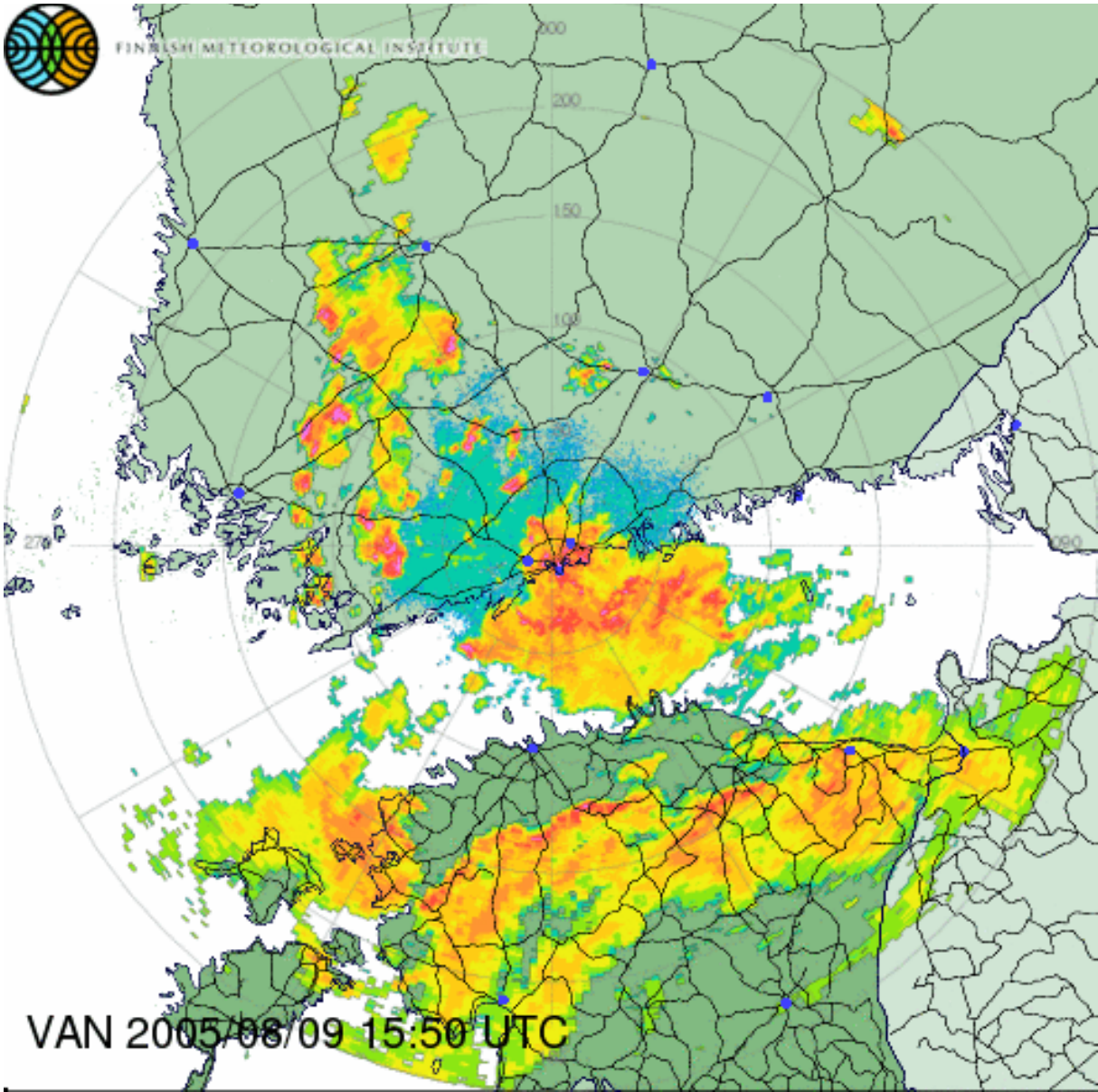
Limitation: predictability in radar nowcasts is commonly shorter than 6 h

Meteorological reasons:

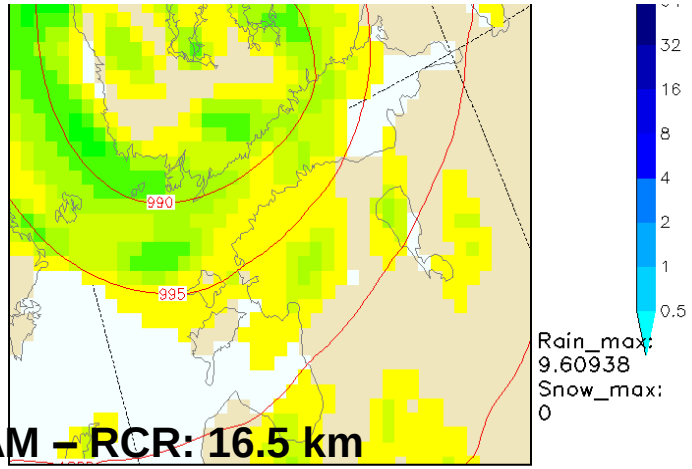
- Growth and decay of rain systems, especially with small thunderstorms.

Other reasons:

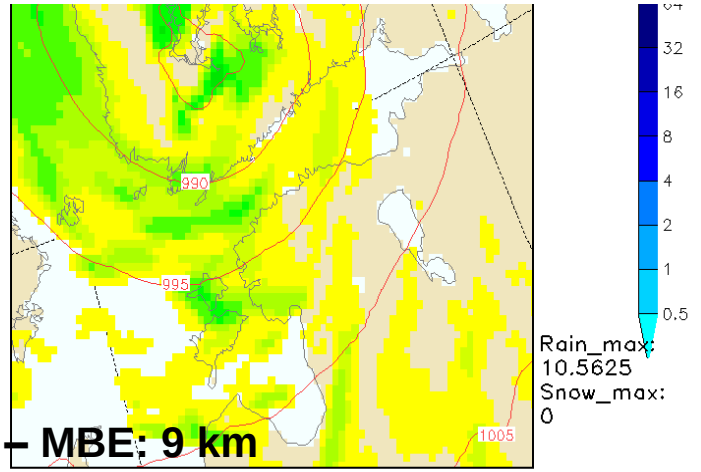
- Quality and availability of radar data.
- Approximations in the nowcasting schemes.



Numerical weather prediction (NWP) applied for 3-96 h forecasts

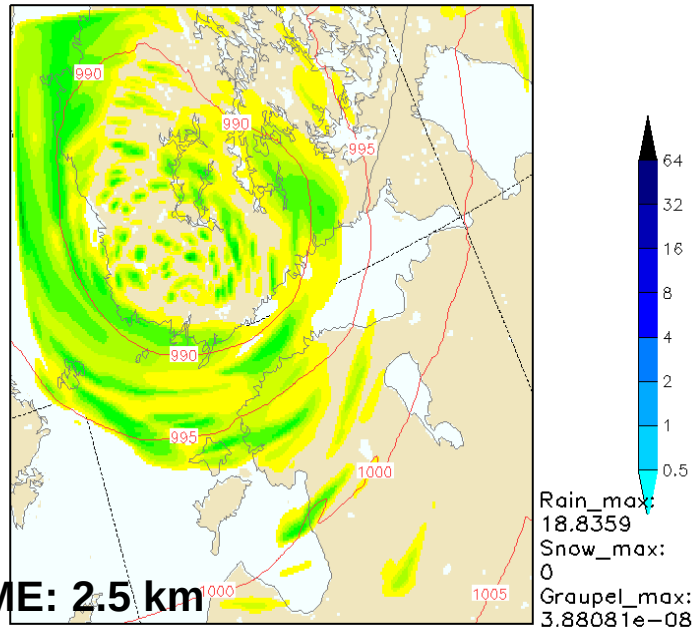


HIRLAM – RCR: 16.5 km



HIRLAM – MBE: 9 km

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



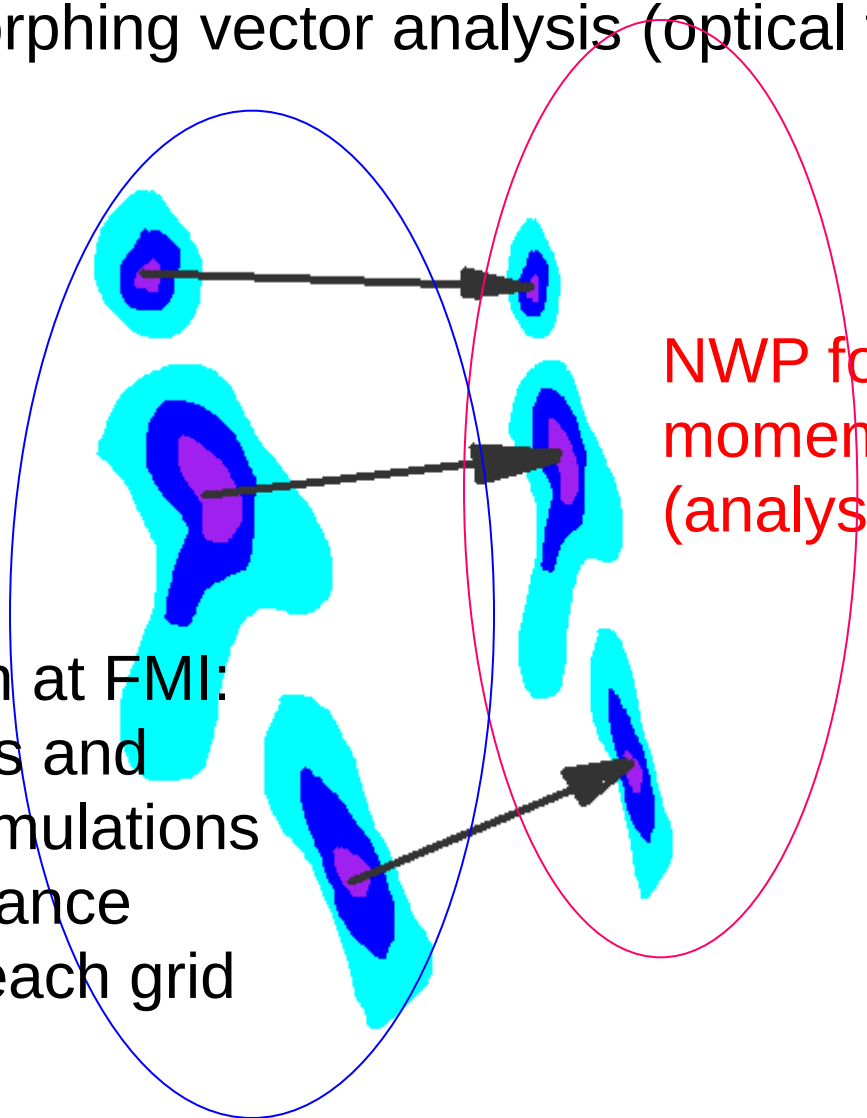
AROME: 2.5 km

- 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.

Seamless blending of radar and NWP ensembles for obtaining integrated forecasts

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

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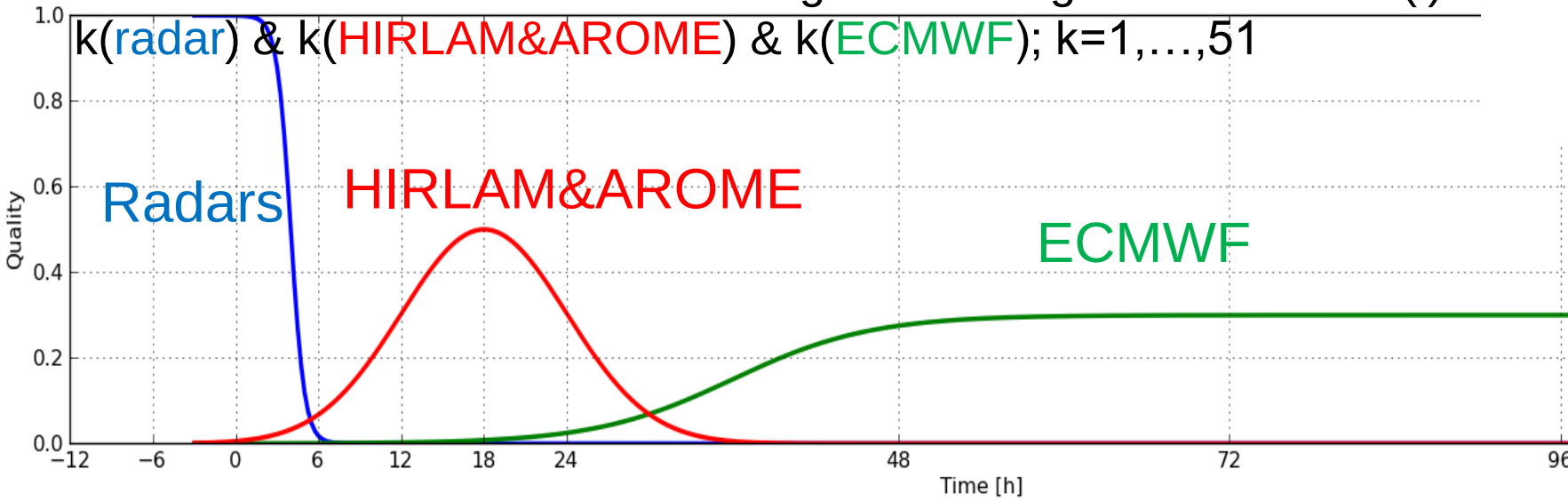
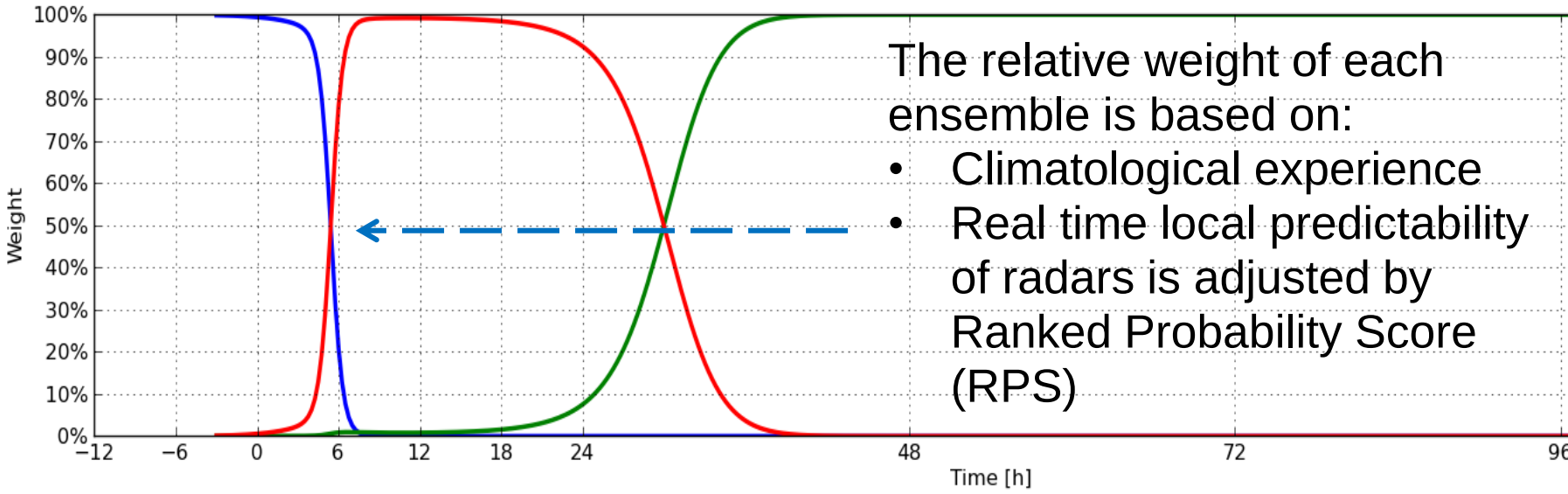
Blending of ensemble members

Blended member with rank k = weighted average of members k(i)

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 (Koistinen et al., 2012).

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Risk management process

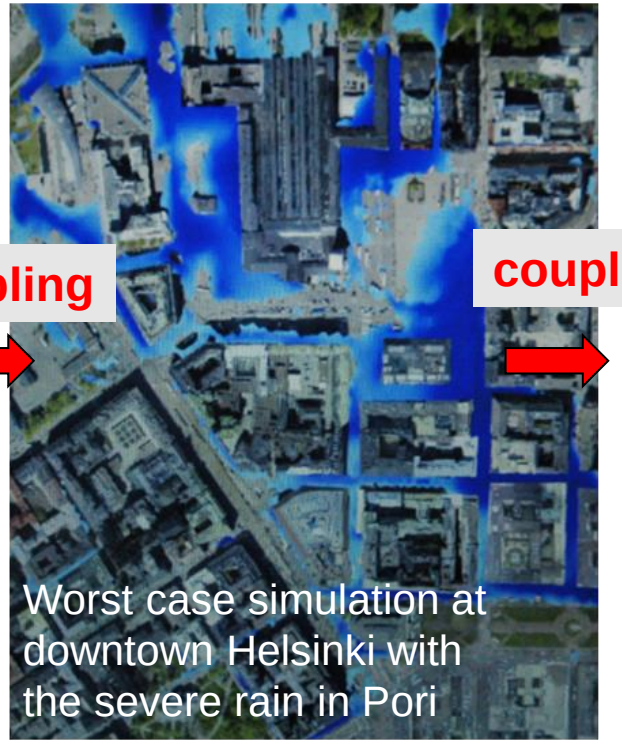
Example: Urban storm water flood risk management and automatic alarming for real estates and rescue personnel was recently tested in Helsinki city center in a pilot study. Three process phases:

1. Rainfall ensembles

2. Water flow and level ensembles

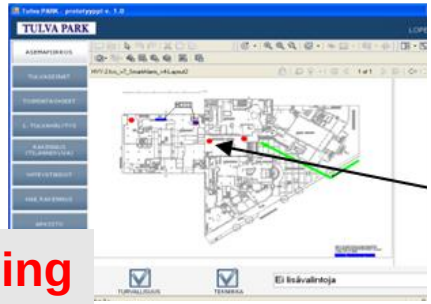
3. Event monitoring, alert and civil protection systems

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 R&D to do as the total process 1+2+3 is operational practically nowhere

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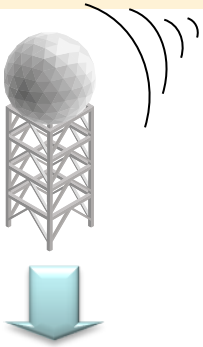
Professional example:

Influent management at Helsinki WWTP

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



Heinonen et al. 2013

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

Conclusions

- Probabilistic forecasts have a great potential in the risk management of extreme rainfall.
- Coupling of rainfall ensembles with hydraulic & hydrologic models and, finally, with risk estimation models 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).
- HAREN & EDHIT: Pilot R&D projects for European radar and NWP based probabilistic precipitation nowcasts: http://ciclo.upc.es/haren/workshop/