Summary of survey as part of the Rainfall Hazards Workshop

As part of the rainfall hazards workshop on the 23rd of March 2023, all participants were asked to fill in a survey prepared by KMI workshop organizers. We have collected the responses from 14 stakeholders based or active in Belgium who are interested in improving current systems linked to observations and forecasting of heavy precipitation, flooding and drought monitoring. Next, you can find the highlights of the survey (3 minutes reading) as well as the collected answers. For visualization purposes, and when it is most representative, we have included graphs such as word clouds and pie charts.

We would like to thank again the speakers and participants.

Sincerely,

The organizers of the Rainfall Hazards Workshop.

A. Take home points

The survey results shed light on various aspects of rainfall observation and forecasting. The specific requirements per application vary significantly, particularly when considering the contrasting demands of high-resolution requirements for pluvial/urban scales compared to lower-resolution but longer-range needs for fluvial scales and even drought monitoring. **A key challenge for the envisioned system lies in effectively meeting the distinct needs of these diverse stakeholders.**

In terms of observations, rainfall data plays a crucial role in multiple applications such as flood forecasting, water management, climatological studies, and risk assessment. The spatial scale of observation ranges from catchment and city levels down to 1 km grid resolution, with the resolution dependent on the specific application. The accumulation periods for real-time systems vary from 5 or 10 to 30 minutes, while other applications like drought monitoring may require accumulations over multiple days.

Moving on to forecasts, the requirements and applications closely align with those of observations. Rainfall forecasts are essential for urban/pluvial and fluvial flood forecasting, as well as dissemination to various stakeholders. The spatial scale of forecasts primarily focuses on the catchment level down to 1 km grid resolution. The time horizons also differ based on the type of event, with forecasts ranging from up to 6 hours for pluvial floods to 1 day to 2 weeks for fluvial floods and water management. Longer-range forecasts of droughts typically span 4-12 weeks.

Temporal resolution and accumulation periods are significant considerations for forecasts. Most users require a temporal resolution of (5-)10 minutes, with the required resolution decreasing as the lead time increases. Accumulation periods in the nowcasting range usually range from 5-10-30 minutes, while longer-range forecasts may involve accumulations over hours or even days. The update frequency varies according to the specific forecast type, with shorter-term forecasts being updated more frequently (e.g., 5-15 minutes for nowcasting) compared to longer-range forecasts that may be updated hourly or even daily for drought scenarios.

The survey also reveals additional products of interest to users such as the type of precipitation, particularly convective precipitation and snow. Both observations and forecasts of precipitation type are considered valuable. Users also express a strong desire for return period information, which helps them assess the likelihood of extreme precipitation events. They also request both full ensemble forecasts and derived quantities such as statistics, intensity, and return period exceedance probabilities.

Validation of forecasts is an important aspect, with users expressing interest in both deterministic and probabilistic validation scores. False negatives (misses) are generally considered worse than false positives. Users are primarily focused on strong intense events, although some are also interested in long-duration events.

Alert products play a crucial role in communicating critical information. Users prefer alerts based on averages over a given area rather than pointwise (street-level) alerts. Preferred alert representations include map/GIS products with a color scale indicating return periods and the probability associated with them. Some users also prefer alerts per polygon/region/catchment rather than a grid-based representation.

The capabilities required for rainfall observation and forecasting involve data formats, processing, and visualization. NetCDF and HDF5 are the most preferred data formats, with some users favoring geotiff, CSV, and TXT. Most users have the ability to reproject and spatiotemporally aggregate gridded data. Half of the users can process ensemble information. Some users express interest in additional consulting on data interpretation, particularly regarding extreme weather and its impact. While the majority have their own visualization tools, some desire additional support in this area. **Additionally, there is a strong demand for a smartphone app targeted at professionals.**

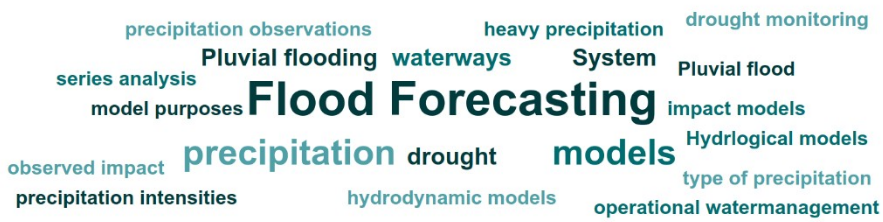
Lastly, the survey reveals other needs of users, including access to experimental products, error statistics, and verification information about biases and errors in forecasts versus observations. There is also a significant need for accurate and timely information on the **impact of rainfall events on specific locations, infrastructures, and communities** to enhance disaster management and emergency response effectiveness.

B. <u>Collected answers</u>

1. For which application/impact model do you need precipitation ***observations***?
    a. Early Warning System (Flood Forecasting) and Integrated Hydrological-Hydraulic modelling

b. Pluvial and fluvial flood forecasting
c. Flood forecasting - navigable waterways // Helping watermanagers with operational watermanagement (high water reporting)
d. We need precipitation observations for several applications and impact models, including flood forecasting, drought monitoring, and assessing the risk of landslides.

4 respondents (**31%**) answered **Flood Forecasting** for this question.



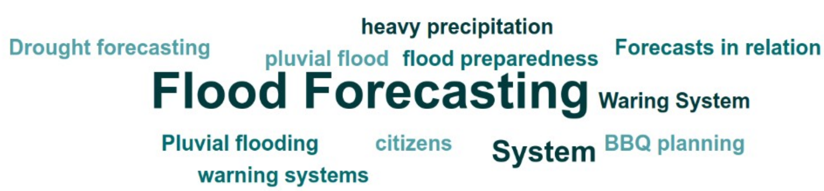
2. What **spatial scale** (county/state, region-level, watershed-level, catchment, grid resolution) do you need for your precipitation observations?
    a. Catchment
    b. catchment and grid resolution
    c. Belgium, most of Flanders and mostly catchment level.
    d. Country scale for EWS, catchment scale for integrated modelling. Fine spatial resolution (500 m - 1 km) to better capture convective storms.
    e. Local to region level
    f. county (30 km around an airport), region level, grid resolution
    g. cities, but the boundaries are also important
    h. Sub-bassin level = 1 km^2
    i. We think 1 km x 1 km should be sufficient, maybe 0,5 km x 0,5 km.
    j. grid resolution (RadQPE)
    k. We calculate area average rainfall for submunicipalities (pluvial) and subcatchments of our hydrological models (1-100km^2) based on the 1km^2 grid which suffices.
    l. The spatial scale that we need for our precipitation observations depends on the specific application or impact model. For flood forecasting, we typically need observations at the watershed-level or catchment scale. For drought monitoring, observations at the county/state or regional level may be sufficient. In some cases, we may also require high-resolution precipitation observations at the grid level for specific applications such as heavy rainfall.

3. What **accumulation periods** of precipitation observations are most useful to you?
    a. Fine temporal resolution to better capture convective storms and rainfall intensity peaks (5-10 min).
    b. high resolution (<=5min) precipitation observations
    c. 30 min / 10 min

d. 30 min
e. 10 minutes up to 1 day
f. 10 min
g. Minutes
h. navigable waterways --> 15min data is fine. 5min even better. Higher frequency not necessary (pluvial floods)
i. different > expressed in terms of return periods
j. Hourly, daily and sometimes higher resolutions, depending on the project scale
k. The accumulation periods of precipitation observations that are most useful to us depend on the specific application or impact model. For flood forecasting, we typically need observations for the past 24-48-72 hours, as well as forecasts for the next 24-48-72 hours. For drought monitoring, we may need observations for longer accumulation periods, such as the past 30 days or even longer. In some cases, we may also require high-resolution precipitation observations at shorter accumulation periods, such as every 15 minutes, to support real-time decision-making during a crisis.

4. For which application/impact model do you need precipitation ***forecasts***?
   a. Early Waring System (Flood Forecasting) and Drought forecasting
   b. urban flood forecasting
   c. Flood forecasting
   d. pluvial and fluvial flood forecasting
   e. Flood forecasting
   f. Prediction of pluvial flooding to be disseminated to internal (city, fire brigade, police, ...) as well as external (citizens, ...) actors.

5 respondents (**38%**) answered **Flood Forecasting** for this question.



5. What **spatial scale** (county/state, region-level, watershed-level, catchment, grid resolution) do you need for your forecasts (and does this vary for different time ranges)?
   a. Catchment level: zeechelde
   b. Catchment
   c. catchment and grid resolution
   d. Country level
   e. Street-level (for shortterm predictions) or catchment level (for longer time ranges)
   f. sub-catchment level = 1 km²
   g. We think 1 km x 1 km should be sufficient, maybe 0,5 km x 0,5 km.

h. submunicipality (pluvial) / subcatchment (1-100km²) but preferably we calculate the area average rainfall ourselves based on the 1x1km² grid. The longer the lead time, the lesser the relevance of the spatial scale.
i. grid resolution (now 4km grid ALARO), finer would be great but on short term. ECMWF finer resolution would also be beneficial.
j. county (30 km around an airport), region level, grid resolution
k. The spatial scale that we need for our precipitation forecasts <u>depends on the specific application.</u> For flood forecasting, we typically need forecasts at the watershed-level or <u>catchment scale</u>. For drought monitoring, forecasts at the county/state or regional level may be sufficient. The spatial scale may also vary <u>depending on the time range of the forecast</u>. For instance, for short-range forecasts (up to 24-48-72 hours), high-resolution forecasts at the grid level may be required. For the following questions, the need for data can vary in terms of frequency, time horizon, resolution and accumulation periods. Whether it is short-term or long-term data, precise or large-scale data, <u>the key is to have a robust and flexible system that can adapt to the unique demands of any crisis</u>. By ensuring that the system can meet these specificities, crisis managers can be better prepared to effectively respond to any emergency.

6. What **time horizon** of precipitation forecasts is most useful to you, and for which applications?
   a. Hours, days
   b. hours (now cast) up to 2 weeks (for buffers)
   c. 1 day - 12 hours - 6 hours - 3 hours - 2 hours - 1 hour - 30 minutes
   d. 3 hours in advance
   e. 3 hours
   f. 3-6 hours for flash floods, 1-7 days for large river floods, 4-12 weeks for drought related applications
   g. a couple of hours (pluvial / nowcasting INCA) up to 15 days (ECMWF)
   h. shorter lead-time (<12 hours) needed for urban modelling, mid-length (2 weeks) for integrated modelling
   i. Pluvial flooding: quantitative rainfall forecast for the next 0,5 hour to 6 hours, qualitative rainfall forecast for the next week (for example it would be interesting to know if weather upcoming week is stable of not, are summer showers likely or not)
   j. short term (2 days) mid term (2-10 days) - longer (1-2 months) for drought forecasting (seasonal forecast) would be interesting (but maybe not very precise)
   k. Days/weeks

7. What **time resolution** of precipitation forecasts periods are most useful to you?
   a. 10 minutes
   b. 30 min / 10 min

c. Minutes, hour, day
d. Several minutes
e. 10 minutes
f. Fine temporal resolution to better capture convective storms (5-10 min), much larger for drought related applications
g. from 10 minutes in the nowcast to hourly in the 48h up to 6 hours in the extended range
h. 15min (2 days) - hourly (2-10days)
i. minutes, hours for longer forecast times
j. multiple > in function of return periods (cumulative rain) - starting at 5 min
k. 10 minutes for the short term quantitative forecasts and daily for the qualitative (likelihood of summer storms) forecasts upcoming week
l. preferably 15' to max 1 hour for the first let's say 5 days. For longer lead times, a lower time resolution is acceptable even though the more the rainfall is spread over time (eg blocks of 6 hours in ECMWF data) the lesser flow will be generated by the hydrological model.

8. Which **accumulation periods** of precipitation forecasts are most useful to you?
    a. < 5min
    b. Minutes
    c. 30 min
    d. 30 minutes
    e. 1 h / 30 min / 10 min
    f. Minutes, hour, day
    g. Minutes
    h. from 10 minutes in the nowcast to hourly in the 48h up to 6 hours in the extended range
    i. 1h, 6h, 12h, 24h, 48h
    j. Fine temporal resolution to better capture convective storms (5-10 min), much coarser for drought related applications (4-12 weeks)
    k. multiple > in function of return periods (cumulative rain) - starting at 5 min
    l. 10' to 1 day
    m. We prefer to receive the highest time resolution possible and are then able to calculate the accumulated rainfall over any period of our interest ourselves.

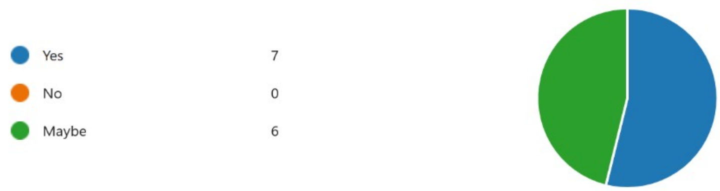
9. How **frequently** would you like a **new** forecast?
    a. 5 min
    b. every 5 min
    c. every 15 min
    d. 4 times
    e. Hourly

f. The now cast part should be very frequent, the longer leadtimes can by 4 times a day
g. High frequency for floodforecasting applications (e.g., 5-10 min for flash floods, 30-60 min for large river floods), much lower for drought related applications (several days should be enough)
h. Depending on the lead time and time resolution. The current frequency of INCA-Alaro-ECMWF is acceptable. If I were to choose which of the 3 would be generated more frequently, I would go for Alaro.
i. Depends on accuracy of the forecast
j. As often as peak precipitations occur.
k. Every hour for the short term quantitative forecast

10. Are you interested on having **precipitation types**? if so which ones, e.g. snow, melting snow, hail, convective precipitation?
   a. Yes
   b. Yes
   c. yes: snow + convective precipitation
   d. snow, melting snow, hail, convective precipitation
   e. Mostly just rain
   f. convective precipitation
   g. convective precipitation
   h. Snow could be relevant because depending on the soil temperature it would or wouldn't melt and thus generate discharge.
   i. Yes, any type of precipitation provides a better understanding of the risk we may face.
   j. yes, drizzle, rain, hail, snow, granular snow, small hail and/or snow pellets, snow grains, freezing rain, graupel, ice pellets, ice crystals,
   k. Not a priority but can be useful
   l. Can be interesting, but is not a priority.
   m. No

11. Would you like to have these precipitation types in real time (observations) or prediction (forecasts)?

12. Would you like to receive information of extreme precipitation events in **return periods**?

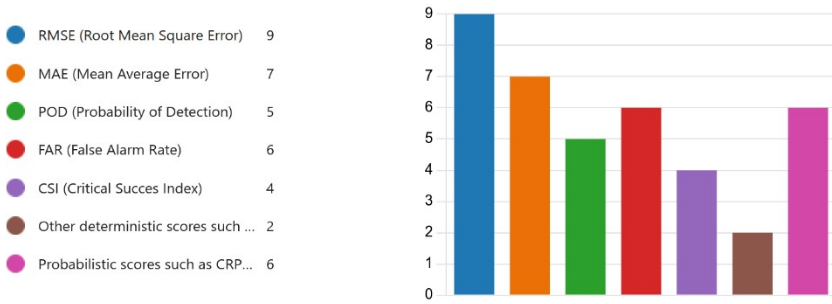


13. Which **probabilistic products** could be useful to you?

14. According to your answer to Question **12**, please provide specifications, e.g., the number of ensemble members, which statistics, precipitation thresholds (mm), return periods (years), and rainfall durations

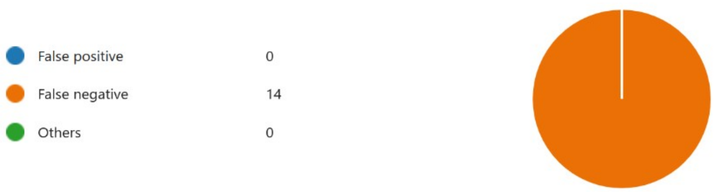
   a. it would be nice to know how much uncertainty is represented for a set of ensemble. For return periods, it would be interesting to have T2, T5, T10, T20, T50 and T100
   b. Return periods related to sewer systems (like T2, T5, T20). Other specification will definitely be useful to but difficult to say at this moment.
   c. Different for every zone according to risk assessment
   d. return period > 10 year, 30 min duration
   e. Return periods: 2, 5, 20, 50 and 100 year.
   f. Since we're recently running very fast hydraulic models, we're able to simulate all ensembles and do statistics on the hydraulic results. Return period exceeding probabilities could be relevant as well to get a quick idea on the locations with most extreme rainfall, the accumulation period that would result in the highest return period, ... allowing us to estimate where and when pluvial/fluvial flooding might occur.
   g. return periods (0.5 / 1 / 5 / 10) - ensemble member statistics: min/max/median P10 90 P20 80 - rainfall durations (15min/1h/12h/24h)
   h. return periods are less useful, they can be useful as a general warning

15. Verification: which **verification metrics** are you interested in?



16. What kind of **weather event** is the most critical for you?

17. What type of **statistical error** is the worst for you?



18. At which **spatial scale** do you need an **alert product** for extreme precipitation?

19. How would you like to represent the alerts, e.g., a map with red = return period of 100 years?
    a. Map
    b. A map
    c. Colored map based on the return periods
    d. For sure a kind of GIS representation - more details are yet to be determined

e. A map with color scale for return periods is indeed useful + indication of probability of the prediction. In addition the corresponding data (5-min) in map / timeseries is useful for use in our data-driven models
f. In a heatmap style graphical presentation.
g. Map with color code for no rain, rain, >5, >10 >,25, >100,, >200, >>200 y return period
h. Map with grid/polygons of administrative areas with color related to the extremity of the rainfall.
i. Map with thresholds per catchment (T1 T10)
j. As a result of a hydrological and or hydrodynamic model

20. Which **data format** do you prefer?

6 respondents (**46**%) answered **netcdf** for this question.

21. Which data format can you handle, e.g., netcdf, hdf5, geotiff, etc?

5 respondents (**42**%) answered **HDF5** for this question.

22. Do you **have** the following **capabilities** in house?

23. Do you need additional services such as **consultation on data interpretation** and application in addition to the products themselves?
a. Yes

b. Yes, would be nice
c. nice to have
d. Yes
e. Yes data interpretation in term of impacts on the ground.
f. Could be useful, especially for extreme weather phenomenas
g. No, the data needs to speak for itself.
h. No
i. No
j. consultation on data format and reprojection (check with your images)
k. We call the RMI operator whenever we want more detailed information.
l. metview is fine

24. Do you have your own **visualization tools**?
    a. Yes (7 times)
    b. QGIS or pyhton produced maps
    c. not fully dedicated, would be nice to have the visualisation tools kmi use for its data
    d. yes, a dashboard called SynApps d
    e. Yes, FEWS/Streamlit dashboards

25. Would you like to have access to estimation/forecasts/alerts on a **smartphone application** targeted at professionals?
    a. Yes (12 times)

26. Do you have other **rainfall hazards needs** that you would like to mention here?
    a. No (3 times)
    b. Intermediary results with which we can already experiment should be nice.
    c. Detection of "gap" between amount of rainfall measured and amount of rainfall forecasted ==> alert when gap is positive, more rain than forecasted (on cathmentlevel)
    d. To fully understand the potential impact of these weather events, it is important to have access to impact data, which can provide insights into how the weather conditions will impact specific locations, infrastructures, and communities. For instance, knowing how much rainfall is expected and how it will impact the water level of a river can help in determining if evacuation orders should be issued or if flood protection measures should

be activated. Impact data can also assist in making informed decisions regarding the allocation of resources and emergency responses. Therefore, having access to accurate and timely impact data is crucial for crisis managers to effectively prepare for and respond to weather-related crises.