WORLD METEOROLOGICAL ORGANIZATION
WEATHER, CLIMATE AND WATER

PROCEEDINGS OF THE WORKSHOP ON IMPROVED METEOROLOGICAL AND HYDROLOGICAL FORECASTING FOR FLOODS IN SOUTHERN AFRICA

(PRETORIA, REPUBLIC OF SOUTH AFRICA, 17-19 NOVEMBER 2003)

PROCEEDINGS OF THE WORKSHOP ON IMPROVED METEOROLOGICAL AND HYDROLOGICAL FORECASTING FOR FLOODS IN SOUTHERN AFRICA

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1. OPENING OF THE WORKSHOP

Mr Mohamed Tawfik of WMO welcomed all participants on behalf of the Secretary-General of WMO, Professor G. O. P. Obasi. He noted the importance of improvement of flood and meteorological forecasting systems in the Southern African region; an area that a number of countries are still behind. Mr Tawfik also thanked the South African Government and in particular the Department of Water Affairs and Forestry for hosting the workshop.

Mr Stefan Van Biljon of the Republic of South Africa (RSA) also welcomed all participants to RSA, and thanked WMO for trusting RSA to be able to host this important workshop. He also made special thanks to the management of the Momentum Insurance Company for their kind gesture of allowing the workshop to be held at their centre.

2. ORGANIZATION OF THE WORKSHOP

2.1 Working arrangements and general information

Mr Datius Rutashobya, the president of CHy, agreed to be the Chairman, and Mr Dumsani Mndzebele from Swaziland was chosen to be the rapporteur (sp). The Agenda of the Workshop is attached to this report (Annex I).

The chairman thanked the RSA for all the arrangements and then invited the workshop participants, coming from the ten countries in the SADC region, to introduce themselves. The attendance list is attached to this report of proceedings (Annex II).

2.2 Background and objectives of the regional workshop

Mr Tawfik outlined the background of the workshop. He observed that numerous examples around the world demonstrate that floods continue to be amongst the most damaging natural disasters. He also noted the high dependence of preparedness and response actions of the various disaster management authorities to prevent or mitigate flood-related disasters on the availability and proper use of accurate and timely meteorological and hydrological forecasting products, yet many meteorological and hydrological services currently do not have adequate means or knowledge to provide extended forecasting services in flood prone situation.

It was therefore noted that the workshop would help improve the capacity of participating countries to improve flood forecasting, improve integration of hydrological and meteorological forecasting and identify major gaps that could be addressed in the second phase of the SADC-HYCOS project. The directors of NMS ad NHS were therefore invited to share their country situation in this field. The principal outputs of the workshop were understood to be as follows:

i. Familiarization with current meteorological and hydrological forecasting systems and methodologies in the region and the use of forecasting products-including climate outlooks-for disaster reduction,

ii. A strategic approach to improve integrated meteorological and hydrological forecasting for floods in the region, including the use of state-of-the-art forecasting technologies,

iii. Identification of case studies demonstrating good practices for potential development of pilot projects in the region.

3. SETTING THE SCENCE – COUNTRY PAPERS

The chairman invited the ten SADC member states represented in the workshop to present their experiences on flood forecasting systems, also commenting on the status of interaction and information exchange between the NMS and NHS in their countries, and the usefulness of the SADC-HYCOS network to flood forecasting. Below is presented the summary of each presentation. The complete country papers are attached to this report (see Appendix I).

BOTSWANA

Flood forecasting in Botswana is hampered by inadequate technology. Communication exists between the NMS and NHS agencies although there is still lack of capacity to forecast rainfall quantities, which makes it difficult to forecast flood magnitudes.

LESOTHO

The Department of Water Affairs (DWA) is responsible for flood forecasting, and flood forecasts and warnings are usually communicated over the radio. The Lesotho Meteorological Services (LMS) is responsible for meteorological network development and weather forecasting. The Lesotho Highlands Development Authority (LHDA) manages the network of dams under the Lesotho Highlands Water Project. Communication exists between the DWA and LMS although coordination of management and plans among the key role players still needs to be strengthened.

MALAWI

Flood forecasting, early warning and disaster preparedness is the responsibility of the Water Development Ministry and the Department of Disaster Preparedness Relief and Rehabilitation. A clearly defined comprehensive tropical cyclone monitoring system is in place and covers the Information stage, Alert stage and the Warning stage. Meteorological information is shared with the Ministry of Water Development for monitoring purposes as an input to flood warning system. To improve flood management system there is need to upgrade the GTS, securing Automatic weather stations (AWS), and financial resources.

MOZAMBIQUE

The National Directorate of Waters (DNA) is responsible for flood forecasting. The flood-forecasting model in use is the “FEWS Stream Model”, an Arcview application model developed to create data input requested by Famine Warning System (FEWS) Flood Model. The National Institute of Meteorology in Mozambique (INAM) provides the seasonal forecast, medium range forecast (4 days) and daily forecast. INAM collects and disseminates daily rainfall data through email to the Water Authorities and Disaster Management Institution. Also satellite imagery is provided every half hour to Water Authorities. A numerical local atmospheric model called RAMS with 40 kilometres of resolution is being tested. Warnings are sent to the print media and local community, to the technical emergency council, to local authorities in the affected areas and decision makers. Press conference and interviews are also held for the public.

NAMIBIA

The Namibia Meteorological Service is responsible for meteorological forecasts and issues products into three categories, namely, public forecast, Aeronautical forecast and seasonal forecast (six months, three months and one month). There is no formal flood forecasting system in place but advisory / alert is forwarded to hydrological services for preparedness / awareness when heavy rainfall is forecast in the catchment areas of over main national dams. NamWater in Namibia Water Corporation – Commercial Bulk Water Supply Organization is in the position of a Telemetric Monitoring System. NHS is responsible for flood management in Interior, border rivers and non-gated dams, while NamWater is responsible for Flood Management in gated dams (reason: Bulk Water Supply) Emergency Management Unit Division under the Office of the Prime Minister is responsible for National disaster preparedness. The Emergency Management Unit operates via focal points representatives in each Ministry. There is adhoc good co-operation for information exchange between the NMS, NHS (National Hydrological Services) under the Ministry of Agriculture, Water and Rural Development) and EMU (Emergency Management Unit) as well as other stake holders.

REPUBLIC OF SOUTH AFRICA

Good working relations exist between the Department of Water Affairs and Forestry (DWAF), responsible for flood forecasting, and the South African Weather Services. A network of 10 radars is in place, covering quite a wide area of the country. Meteorological products include seasonal, monthly, 14-days, 7-days, 24 hours, and even smaller time-step rainfall forecast, and other products crucial to flood forecasting. Severe weather warning is disseminated through SMS near real-time. A good network of over 200 real-time water flood-monitoring stations is in place. A fully-fledged flood forecasting system that is adequately informed by meteorological products exists in the DWAF. Forecasts of rainfall quantities are done, but on trial basis at the moment, and thus this product is not yet available to potential users or public.

SWAZILAND

The National Meteorological Services is responsible for meteorological forecasts, and issues products are into two categories namely, public forecasts (lunchtime and hourly forecasts and four ay forecasts) and seasonal forecasts (6 months, 3 months and monthly rainfall and temperature forecasts). There is no formal flood forecasting system in place, but meteorological products do inform dam operators. Good communication exists between the NMS and the NHS. Capacity issues to enable flood forecasting are being addressed in the ongoing institutional reforms facilitated by the new water legislation.

TANZANIA

There is no agency doing formal flood forecasting, but a very good observation network is in place. Automatic weather stations have been installed but are not yet in operation.

Some of existing DCPs are not transmitting water level information, and this tends to limit flood monitoring. Very good working relations exist between the NHS and the NMS institutions, an arrangement that still has to be formalized.

ZAMBIA

There are 36 climatological stations, whose information is supplemented with information from the SADC-HYCOS network. The Department of Water Affairs, Disaster Management and Mitigation Unit and the Early Warning Unit, which brings together quite a number of stakeholders, are major users of the meteorological products. The products include seasonal rainfall forecasts, 7-day forecasts, satellite images, 10-day bulletins on rainfall patterns, etc. Good interaction exists between the NMS and the NHS. Communication means include e-mail, fax, phone, radio, T.V., face-to-face, Radio-Internet (RANET) etc. A vulnerability Assessment Committee also exists to facilitate coordination of mitigation measures, when there is need. There is no comprehensive approach to flood management, and there is no dedicated flood-forecasting unit in place. Otherwise flood management is the responsibility of the Zambezi River Authority and ZESCO, a hydropower generation company.

ZIMBABWE

The Department of Meteorological Services issues daily and 10- day weather forecasts for the general public. The Central Forecast Office also issues meteorological warnings and advisories to TV and radio stations and advisories any time. Forecasts of severe weather are also issued 10 days in advance. This information is derived from data from a network of 1000 meteorological stations, satellites, 4 weather radars, and from other countries in the region. One of the radars has been calibrated to give nowcasts of volumetric rain rates in millimetres. Zimbabwe National Water Authority (ZINWA) has no operational flood forecasting method at the moment, but there are some flood forecasting models that are on trial using satellite rainfall estimate (Cold Cloud Duration (CCD). Flood warnings are issued when river flow levels are dangerously high and when the floodgates of major dams are about to be opened. If floods caused by organized systems like low pressure and cyclones are detected during the weather briefings, heavy precipitation outlooks are prepared and relayed to the Civil Protection Unit, ZINWA, as well as general public through the radio, telephone, T.V., press, fax and Internet.

4. DISCUSSION ON STRENGTH, WEAKNESS, OPPORTUNITIES AND THREATS IN THE REGION

The workshop undertook a SWOT analysis of flood forecasting in the region and its findings are presented below.

STRENGHTS

- Well established meteorological institutions/offices
- Data collection systems exist
- Met/Hydro sector collaboration
- Availability of better tools in some countries e.g. Radars, Satellites, Models
- Regional community (SADC) and regional sectoral establishments e.g. SADC Water Sector, Drought Monitoring Centre, etc

OPPORTUNITIES

- Recognition of the need for flood forecasting
- Political awareness
- Availability of modern information technology and communication
- Willingness and involvement of international cooperating partners
- Some skilled personnel available in the region
- Access to available material, literature, etc.

WEAKNESSES

- Absence of flood forecasting systems in most countries
- Weak data transmission networks/means
- Weakness in utilization of data collection network
- Lack of quantitative rainfall forecasts (QPF)
- Lack of adequate real-time data collection
- Shortage of qualified personnel

THREATS

- HIV and AIDS
- Brain drain from the region
- Budgetary constraint

5. INSTITUTIONAL REQUIREMENTS – INCLUDING CAPACITY BUILDING – TO IMPROVE FLOOD FORECASTING

Following the SWOT analysis of the regional flood-forecasting situation, the workshop identified the following institutional requirements to improve flood forecasting.

i. A legal framework needs to be put in place, and roles and responsibilities of required institutions defined
ii. Adequate data collection network in place
iii. Capacity building
- Training
- Retention scheme and enabling environment
- Career development
- Provide necessary equipment and tools
- Assessment, adaptation and adoption of new emerging technologies

iv. Strengthening of cooperation/collaboration between NMHS and other institutions.

6. EMERGING NEW TECHNOLOGIES IN OBSERVATIONS, TELECOMMUNICATIONS, DATA PROCESSING AND ANALYSIS

6.1 Observational Networks

Mr Eugene Poolman presented on the experience of South Africa on observational networks and real-time data. He discussed modern electronic based observation systems, the new approach to rain gauges whereby real-time communication is realised through use of cell phones. Already 20 rain gauges are operated on real-time. He also discussed automatic weather stations, national weather radar techniques, the TITAN system and satellite techniques.

Of particular importance to the workshop was the realization of what radar can do to give an indication of runoff.

The workshop noted that modern and sophisticated systems are already in place, and that what is required is to understand how these technologies can best respond to flood forecasting needs. The importance of integration of data and human experience was also underscored. The complete paper is annexed to this report.

6.2 NWP forecasts and State-of-the-art meteorological models

Mr Eugene Poolman again presented on this item sharing on South Africa's experience in the use of Numerical Weather Prediction models. He discussed the MM5 Mesoscale Model, the Eta regional model, medium range forecasting using the ensamble forecasts and the Streamflow Model (ECHAM3-MOUS). He observed that the accuracy of the NWP has increased with time. Mr Poolman challenged hydrologists to find out what they can do with the products that are now at their disposal, to improve flood-forecasting systems in the region.

The workshop noted the need for working together between the hydrologists and the meteorologists in the necessary integration of efforts. In this vein the workshop noted the need to expose young hydrologists to the meteorological forecast and meteorologists to flood forecasting, if the desired integration were to be meaningful. The complete paper is also annexed to this report.

6.3 State-of-the-art hydrological modelling and forecasting

Mr Paolo Reggiani presented his experience on working on the MUSIC Project, founded on the European Flood Forecasting System. This constitutes an open architecture for operational platform for incorporating, interlinking meteorological forecasts with hydrological and hydraulic models to various locations in a catchment. The DEM, Soil Type and Land Use information is used to calibrate the rainfall-runoff model of interest, the TOPKAPI model, applied to model the Reno River. The model also has a wide application in Italy. The paper is also annexed to this report (see Appendix 2).

6.4 Presentation of the result of the Expert Meeting on "Global/Regional Short-term Hydrological Forecasting Systems"

A report of the exert meeting on the development of the CHY Project "Global/Regional Short-term Hydrological Forecasting System" held in Pretoria, South Africa, on the 13-15 November 2003, was presented to in the workshop. It was also reported that in the workshop of the experts two basins in the sub-region, the Limpopo and Zambezi basins, had been identified as pilot basins for the application of the risk management guidelines. The workshop was also informed that the same basins had been identified as the two basins from the sub-regions earmarked to receive the EU support through NEPAD whereby a total of 10 basins will receive such support, 2 from each sub-region (see Appendix 1).

7. CHALLENGES AND OPPORTUNITIES OF ENHANCED COOPERATION AMONGST NMHSs IN THE REGION FOR BETTER PRODUCTS

Challenges

- Use of the Global Telecommunication System (GTS) to service needs of both meteorological and hydrological nature, including its use to transmit data from the SADC HYCOS network.
- Strengthening of the Drought Monitoring Centre (DMC) to address hydrological forecasting needs.
- Getting the hydrologists and meteorological experts to talk together, and second hydrologists to be exposed to the meteorological services activities.
- Getting hydrological and meteorological experts work together to forecast floods before the rain touches the ground.
- Having a direct computer link between the NMS and the NHS
- Making available technology (e.g. radar) fully operational

Opportunities

- Hydrologist to find out how they could make best use of the QPFs in hydrological forecasting
- Increase of frequency of flood disasters provides an opportunity to cooperate and to seek funds and be heard.

8. STRATEGIES TO IMPROVE INTEGRATION OF METEOROLOGICAL AND HYDROLOGICAL FORECASTING OF FLOODS

- Having QPEs for small-scale catchment scale, e.g. Quaternary catchment level
- Joint research projects on flood forecasting systems and models.
- Interchange of professionals between the NMS and NHS.
- Undertake case studies
- Identify means of communication that are reliable and fast
- Need for QPFs of short time scale, say 7-days.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

- Hydrological forecasting for floods in the region is very important
- Acknowledge limitation of present meteorological products and advance from there
- The meteorological products that are presently available are not ready for flood forecasting
- To get talking together to each other is the biggest challenge. This will cover the needs of each other and the information package and dissemination
- Capacity building in flood forecasting is essential, both for the human resource and technology including computers so that trainees can continue working on flood forecasting in their respective countries.
- A majority of countries have some stations that are not functioning properly
- There is no flood forecasting system in operational among most SADC countries that participated at the meeting
- The hydrological community requires quantitative precipitation forecasts from the meteorological community

- Communication between the hydrological and meteorological community is not satisfactory

9.2 Recommendations

- Attachments/secondments of professionals at the NMHS for joint research projects on flood forecasting, and general exposure into what each is doing.
- Regular meetings of focal points between NMS and NHS
- Involvement of NMS staff in case studies that are directly for floods forecasting in order for them to recognise their short-coming
- On-line communication networks
- Encourage communication
- Establishment of SADC-approved centres of excellence
- Encourage interaction between water agencies, e.g. SADC Water Division and DMC.
- Establish a working committee on meteorology and hydrology in our countries
- Organise a workshop on flood forecasting every year
- Next Southern Africa Regional Climate Outlook Forum (SARCOF) to include quantitative forecasts
- Take advantage of the high political awareness on flood issues to push the flood-forecasting agenda to the forefront.
- Countries should look at the dwindling network in both meteorological and hydrological observation
- Strengthen the hydrometeorological data collection network on near real-time basis.
- Enhance technical capabilities in modelling and forecasting for different time scales.
- Undertake assessment, design and installation of optimum network of stations (basin-wise) to be equipped with real-time transmission equipment.
- Expand the SADC-HYCOS project network - more real-time river stage data collection stations are needed, and locate the transmitter and logger at real-time data at a high level so it would not be destroyed by small floods.
- For the second SADC-HYCOS project, location of the stations should be in basins with flood-prone areas, and should have enhanced communication systems.
- Collaborations between the NMS and NHS institutions should be enhanced, and where not in place, should be formalised.
- Human resource development, e.g. recruitment and training to be expedited.
- Strengthening of equipment capabilities and other tools Automatic Weather Stations (AWS)
- Provide an enabling and responsive environment for officers in the NMS and NHS.
- Encourage participation of women in flood forecasting programmes.
- The Met services need to develop the relevant products for hydrological use in flood forecasting through development of their capability in QPF, use of available technology such as ensemble products, NWP to guide QPF forecasts and collaboration with other NMSs and RSMC-Pretoria.
- Investigate the use of systems, like the one developed by the USGS for the Limpopo basin and other river basins, to help in early warning of potential flooding, that is also useful for scenario testing.
- Adopting pro-active information exchange systems
- Setting up focal points between riparian states for flood warning systems, for alerts and awareness.
- Full exploitation of available products.
- It is recommended for hydrological personnel to be attached to the national meteorological services at the operational level.
- Regular meetings of focal points should be encouraged (including attendance at medium- range forecasts. At these meetings any outstanding or pertinent issues can be addressed.
- Establish on-line communication channels and facilities

- Hydrologists should recognise the limitations of the currently available meteorological products and make the best use of them to achieve flood forecasting objectives.
- Identify SADC- approved centres of excellence for flood forecasts for the purposes of capacity building, refresher courses and research
- Encourage inter-agency collaboration among SADC recognised/ appointed regional authorities (e.g., DMC, FEWS NET, SADC Water Sector)
- A regional workshop on flood forecasting at the research and operational level be conducted so that models with realistic scenarios can be identified and recommended
- For meteorologists, the next Southern Africa Regional Climate Outlook Forum (SARCOF) should incorporate quantitative forecasts/ estimates for the hydrological community.
- Give a social and an economical dimension of meteorological and hydrological instrumentation.
- Meteorologists need to understand information that is needed by hydrologists and disaggregate precipitation forecasts from the regional or national level to basin level.
- Hydrological community can build capacity towards national flood forecasting by using simple hydrological models to simulate response of various basins.
- Meteorological and hydrological services should make maximum use of communication equipment to ensure easy access of meteorological and hydrological products and information in the internet.

10. CLOSURE OF THE WORKSHOP

The chairman invited Mr Jerry Lunguasa, the Permanent Representative of the Republic of South Africa with WMO, to close the workshop.

Mr Lunguasa wished participants a safe journey home. He expressed his hope that participants had been greatly challenged by the workshop. He also expressed his happiness to see an interaction of the meteorologists and hydrologists. He also resounded the need for interfacing of the meteorological and hydrological side of the flood forecasting business, and expressed his wish that even the academic institutions could start early introducing this crucial integration.

Mr Tawfik also expressed WMO's gratitude to RSA for ably hosting the workshop, thanking both the South African Weather Service and Department of Water Affairs for everything. He also thanked all participants, and particularly noted that meteorological experts had come in their numbers, to a flood-forecasting workshop.

The Chairman also thanks all participants for making possible for the smooth progress of the workshop.

ANNEX I

WORLD METEOROLOGICAL ORGANIZATION Doc. 1

REGIONAL WORKSHOP ON IMPROVED METEOROLOGICAL
AND
HYDROLOGICAL FORECASTING FOR FLOODS
IN SOUTHERN AFRICA

PRETORIA, SOUTH AFRICA, 17-19 NOVEMBER 2003

AGENDA

1. OPENING OF THE WORKSHOP

2. ORGANIZATION OF THE WORKSHOP

3. SETTING THE SCENE – COUNTRY PAPERS

4. DISCUSSION ON STRENGTH, WEAKNESS, OPPORTUNITIES AND THREATS IN THE REGION

5. INSTITUTIONAL REQUIREMENTS – INCLUDING CAPACITY BUILDING - TO IMPROVE FLOOD FORECASTING

6. EMERGING NEW TECHNOLOGIES IN OBSERVATIONS, TELECOMMUNICATIONS, DATA PROCESSING AND ANALYSIS
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7. CHALLENGES AND OPPORTUNITIES OF ENHANCED COOPERATION AMONGST NMHSs IN THE REGION FOR BETTER PRODUCTS

8. STRATEGIES TO IMPROVE INTEGRATION OF METEOROLOGICAL AND HYDROLOGICAL FORECASTING OF FLOODS

9. CONCLUSIONS AND RECOMENDATIONS

10. CLOSURE OF THE WORKSHOP

ANNEX II

WORLD METEOROLOGICAL ORGANIZATION

Inf. 1

REGIONAL WORKSHOP ON
FLOOD MANAGEMENT IN SOUTHERN AFRICA

PRETORIA, SOUTH AFRICA, 17-19 NOVEMBER 2003

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APPENDIX 1

REPORT TO THE

REGIONAL WORKSHOP ON IMPROVED METEOROLOGICAL AND HYDROLOGICAL FORECASTING FOR FLOODS IN SOUTHERN AFRICA

FROM THE

EXPERT MEETING ON THE DEVELOPMENT OF THE CHy PROJECT "GLOBAL/REGIONAL SHORT-TERM HYDROLOGICAL FORECASTING SYSTEM" PRETORIA, REPUBLIC OF SOUTH AFRICA, 13-15 NOVEMBER 2003

1. BACKGROUND

1.1 At the kind invitation of the Republic of South Africa and with support of the South African Weather Service and the Department of Water Affairs and Forestry, the Expert Meeting on the Development of the CHy Project "Global/Regional Short-term Hydrological Forecasting System" was held at the headquarters of the SAWS in Pretoria, Republic of South Africa, from 13 to 15 November 2003. The Expert Meeting was attended by 11 participants from 9 countries (Annex A).

1.2 The objectives of the meeting were:

a) To enable the expert and some of his associate experts to present the findings of their work for consolidation into a report to CHy –XII – Flash Flood Threshold Pilot Project;

b) To present the status of the development of the FFTPP and to assess the possibilities and convenience of extending the application of the methodology to other regions, primarily to Africa;

c) To present relevant related experiences of other projects (even where these projects do not focus specifically on short-term hydrological forecasting), such as those being developed by the USGS, and the European Flood Forecasting System (EFFS) and the International Flood Network (IFNET);

d) To develop material that could be used as inputs to Regional Workshops on Flood Forecasting;

e) To prepare a first outline of the related needs for hydrological forecasting in the different regions, including current capabilities;

f) To compile a report and set of recommendations for consideration at CHy-XII.

2. QUANTITATIVE PRECIPITATION ESTIMATION AND FORECASTING

2.1 For the purpose of the Expert Meeting, Quantitative Precipitation Estimation was defined as the estimations of precipitation that has fallen up to the present time, that is rainfall over the past hour, 3 hours, day, etc, to the current time. This precipitation can be estimated from ground-based rainfall monitoring stations, analysed radar or satellite data, or any combination of these. Quantitative Precipitation Forecasting was defined as the forecast of possible rainfall from current time onwards.

QPF can be derived from modelling and progressing current radar and satellite images forward in time or by the use of the outputs from global and regional Numerical Weather Prediction models.

Nowcasting techniques focus on the next 0 to 6 hours, while NWP can provide estimates of rainfall out to 10 days.

2.2 Hydrological modelling (comprising rainfall-runoff modelling, routing and other techniques) are used to convert the QPE and QPF estimates to hydrological parameters such as river flow and in turn to river height (flood hydrographs and inundation areas). Hydrological models are calibrated using historical data, can be updated in real-time using catchment characteristics provided in real-time (such as soil moisture, evaporation, etc.) and then used to forecast hydrological conditions using QPE and QPF. Uncertainty in the estimates of QPF is a key issue and one that is sometimes addressed by using ensemble (a number of possible outcomes) forecasts.

3. CASE STUDIES OF HYDROLOGICAL FORECASTING USING QPE AND QPF

3.1 During the Expert Meeting, five methodologies that involve the use of QPE and QPF were presented. A brief description of the presentations is provided in Annex B. A comparison of the technical aspects of the methodologies described is provided in Annex C. The methodologies presented were:

(a) Mr Sergei Borsch – CHy Expert – Russia - Case Study for the Kuban River Basin
(b) Mr Nick Graham – US Hydrologic Research Centre – The Central America Flash Flood Guidance Project
(c) Mr Hussein Gadain – USGS – Famine Early Warning System Network (FEWS NET) and a case study for the Limpopo River in Mozambique
(d) Mr Paolo Reggiani – Delft Hydraulics – European Flood Forecasting System (EFFS)
(e) Mr Akira Sasaki – Infrastructure Development Institute – Japan – International Flood Network (IFNET)

3.2 Mr Hussein Gadain also made a presentation on a methodology to downscale climate forecast information (4 month outlooks). In response to the climate prediction information users community, USGS developed software for downscaling the climate prediction information produced by some of the regional and international climate prediction centers into scenarios useful for crop and flood monitoring. These centers include the Drought Monitoring Center in Nairobi (DMCN), which monitors the Greater Horn of Africa (GHA), The Drought Monitoring Center in Harare (DMCH) for monitoring Southern Africa Region, the ACMAD centre in West Africa and the International Research Institute for Climate Prediction (IRI), among others. USGS produces supplementary reports to the climate forecast generated by these centers. The flood monitoring process is the targeted on those basins that are subject to high probabilities of rainfall as given by the forecast.

4. CAPABILITIES AND LIMITATIONS OF THE METHODOLOGIES

4.1 Discussion on the capabilities and limitations of the methodologies was undertaken in the form of a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis. The outcome of this SWOT analysis is provided in Annex D.

4.2 In summary, the following conclusions were made:

Strengths

QPE and QPF offer the opportunity to improve flood warning lead-times and accuracy. There is a high demand for hydrological products and services that take into consideration possible future climate (especially rainfall) conditions (including flood management and water resources management). The increasing availability of remotely sensed and derived observational data from radar and satellite systems and improved modelling capabilities have improved hydrologists' access to and potential use of QPE and QPF. Better access to real-time rainfall has provided an improved capability to ground-truth remotely sensed data. New systems will provide higher resolution and thus improved outputs for use by the hydrological community. The community at risk of flooding and the potential damage that floods can cause are increasing and thus improved flood forecasting capabilities will be required. Hydrological model are also improving and once combined with QPE and QPF can produce high quality operational products.

Weaknesses

In many regions of the world, the scarcity of ground-based monitoring stations (rainfall, radio sondes, etc) is a limiting factor and impacts on the quality of the QPE and QPF estimates. The access to radar and satellite data and NWP model output is not always easy. The derivation of QPE/QPF remains a complex activity and the technical and scientific skills required are not readily available. Calibration techniques for radar and satellite derived rainfall data still require further development. A good composite QPE estimate capability (ground-based, radar and satellite data) is not available. The focus of QPF is on meteorological requirements as opposed to hydrological requirements. Current activities are "Developed World" focussed and many methodologies are still experimental. The hydrological modelling community needs to be able to alter/change its approach in response to these new capabilities.

Opportunities

A common format for satellite data and radar data and the derived rainfall fields would provide a significant platform for future development. There is a strong need for QPE and QPF and associated hydrological forecasts in a range of areas, including agriculture, pastoral, water resources distribution. The hydrological community should play a greater role in future NWP developments and have their requirements ready to place on the table. Greater cooperation between the meteorological and hydrological community is required. Improving satellite capabilities will lead to better QPE estimates.

Threats

QPE/QPF capabilities should not result in a reduced need for ground-based stations. If anything, the availability of ground-based stations will be more important. There may be impacts on the role and responsibilities of NMS's and NHS's and they should be provided with the tools and skills to meet these challenges. There are significant concerns if the gap between hydrologist and meteorologists widen. Meteorologists could take on the role of hydrological modelling in NWP's and the outputs may not be in the format or type hydrologists require. There will be a dependence on real-time data, both meteorological and hydrological for the systems to work and access to this data will need to be maintained. The cyclic nature of flood and droughts means that public awareness and interest is highly variable.

4.3 The hydrological community can make significant advances through the use of QPE and QPF and we must work closely with the meteorological community to achieve this. The roles, responsibilities and linkages between all groups involved in the provision of flood warning services must be taken into consideration. The role of flood forecasting is a chain of activities from monitoring through analysis and forecasting to warning and community response and review of operations. This chain is only as strong as it's weakest link. While, the focus of QPE and QPF is on improving the accuracy and timeliness of flood forecasts, it was important to remember that these are only two of the elements of the total flood warning system. Achieving positive outcomes through reduced loss of life and property damage remains the primary focus of flood forecasting and warning systems.

5. CHy PROJECT ON GLOBAL/REGIONAL SHORT-TERM HYDROLOGICAL FORECASTING SYSTEM

5.1 The Expert Meeting discussed the CHy Project "Global/Regional Short-term Hydrological Forecasting System". All of the participants agreed to contribute to the further development of the project outline and made the following recommendations:

- The tools should be tested in different river basins (in particular, in an arid/semi-arid region),
- Preference should be given to river basins that are multi-national,
- The involvement of the Regional Association I (Africa) WMO Working Group on Hydrology should be sought, and
- Possible river basins in Africa include: the Limpopo, Lake Victoria, a river basin in West Africa.

5.2 The Expert Meeting identified the following possible stages for the Project:

- A compilation of the approaches (QPE, QPF, etc),
- A study identifying in greater detail the strengths and weaknesses of the approaches,
- A comparative testing of targeted elements of the forecast capability,
- Development of a prototypical composite system or systems, and
- Preparation of project packages for funding (including a needs assessment).

6. CONCLUSION

6.1 The material provided in this paper has been extracted from the report of the meeting, which is in draft format, and the Experts have requested the WMO Secretariat to make any editorial changes deemed necessary to the final report of the meeting.

Bruce Stewart
Chair
Expert Meeting on the Development of the CHy Project "Global/Regional Short-Term Hydrological Forecasting System"

ANNEX A

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ANNEX B

PRESENTATIONS ON QPE AND QPF USE IN HYDROLOGICAL SHORT-TERM FORECASTING EXPERT MEETING ON THE DEVELOPMENT OF THE CHY PROJECT “GLOBAL/REGIONAL SHORT-TERM HYDROLOGICAL FORECASTING SYSTEM”

1. CHy Expert on Short-Term Hydrological Forecasting

1.1 Mr Sergei Borsch reported on the activities he has undertaken in relation to his role as the CHy Expert on Short-Term Hydrological Forecasting. In his presentation, he noted that for last 10-15 years an increasing trend has been observed in number of flooding events in various regions of the world, and that the number of people injured from flooding and the damage had also increased. These facts support the requirement to develop reliable forecasting systems (on regional, national and global levels) to enable mitigation of the consequences of flood events.

1.2 The basic stages of short-term hydrological forecasting systems development were presented using the example of a Regional Project on floods forecasting (including flash floods) in the Kuban River Basin.

1.3 Mr Bosch described the different types of floods, however in his representation the expert focused on floods that are connected with heavy rains, including so-called “flash floods” because they impact on a greater area of the world than other types of flooding (for example, snow melt, ice jams and mixed floods).

1.4 Over the past two years, the Expert has collected, compiled and analyzed an extensive range of material on the methods of QPE and QPF, including radar rainfall estimation methods, the accuracy of QPF, hydrological models and their use in operational hydrological practice, the accuracy of forecasts of rain and associated floods, etc.

1.5 Mr Bosch’s other main activity has been the management of and participation in the CHy Project on Global/regional project on short-term forecasting of floods. In his presentation he used the example of regional forecasting within the Kuban River Basin to show the basic directions and approaches to forecasting of floods he has developed, and also the methods of QPF and their use in operational hydrological practice. He noted that there are currently a range of QPF methods available and there have been many positive reports of use of these methods and technologies of QPF in operational hydrological practice. Most of these studies have been reported separately and there is a lack of an overall consolidated report on experiences in the use of forecasts of precipitation in hydrological models, especially for average and large catchments.

1.6 The principal causes of the lack of information on the use of QPF in hydrological models and techniques include:

(a) The absence of close cooperation between meteorologists and hydrologists even in cases where they work in one combined forecasting center;

(b) The different requirements in estimating QPF for both meteorologists and hydrologists; Meteorologists are interested in the possibility of strong precipitation, and the general location of where it will fall. Hydrologists would like to know the quantity of precipitation that is predicted, and exactly where it will be observed. It is especially important to know the precise location of the precipitation in the case of strong (convective) precipitation that has disparate structure and is focused on a small area.

(c) It is difficult to determine the phase of precipitation, especially in mountain regions where in the different high-altitude zones the liquid, firm or mixed precipitation can drop out.

2. The Central America Flash Flood Guidance Project

2.1 Mr Nick Graham reported on the Central America Flash Flood Guidance project (CAFFG). CAFFG is being implemented by the Hydrologic Research Center in San Diego, CA to detect and quantify flash flood threat for the seven countries of Central America. The development of this system has been funded principally by the US Agency for International Development Office of Foreign Disaster Assistance through the National Oceanographic and Atmospheric Administration Office of Global Programs. Completion of the project is scheduled for the end of spring 2004. The system will be housed at a regional center in the Costa Rican National Meteorological Institute (INM).

2.2 The CAFFG system consists of seven components:
a) a module to produce a gridded rainfall analyses from remotely sensed and *in situ* data,
b) a soil moisture accounting model,
c) a threshold runoff model,
d) a flash flood guidance model,
e) a dissemination system, and
f) a training module.

2.3 The rainfall module fuses satellite IR data (produced by a co-located NOAA NESDIS satellite data downlink and processing system) with *in situ* gauge data at time scales of 1-2 weeks at 4 km spatial resolution. The soil moisture accounting model uses digital elevation (currently 1 km resolution), land use, and soils data together with the precipitation estimates to produce soil moisture deficit estimates at time scales of 1-2 weeks for basins with areas on the order of 1000 sq km^2. The threshold runoff model utilizes basic characteristics of catchment geomorphology to produce estimates of "threshold runoff", the amount of effective rainfall required over a given duration to produce bankfull flow at the outlet of the catchment assuming saturated soil conditions. These estimates have been produced over catchments of 100-300 km^2.

2.4 The flash flood guidance model merges the information from the soil moisture and threshold runoff modules to estimate the amount of rainfall necessary to first saturate the soils in a given small catchment and then produce bankfull flow at time scales of 1, 3, 6, 12, and 24 hours. The flashflood guidance and related products (e.g., rainfall and soil moisture deficit estimates) will be disseminated from the regional center via Internet, fax, phone and other means. The training module will provide training for system maintenance, the essential physics underlying the flash flood estimates, and interpretation of output products.

2.5 Key points to note about this system include the following: A) the underlying assumptions obviate the need for a flow routing model with the attendant requirements for streamflow observations and tuning B) the system depends principally on globally available digital data (elevation, soils, land use) and requires relatively little *in situ* data (at the same time, accurate in-region data can improve system performance). These attributes allow the system to be readily implemented at modest cost to provide full coverage for large regions with sparse observational networks. Higher resolution terrain (e.g., 90 meter) and precipitation data (e.g., from satellite or radar) would allow the flash flood guidance to be prepared over catchments smaller than the 100-300 km^{-2} used in the CAFFG project. Additionally, the inclusion of forecast precipitation data from numerical models would allow the production of flash flood guidance at longer lead times. Further information concerning the CAFFG project can be found at http://www.hrc-web.org/Technology) under Projects with Global Applicability.

3. United States Geological Survey (USGS) – Famine Early Warning System Network (FEWS NET)

3.1 Mr Hussein Gadain outlined aspects of the USGS FEWS NET program. In this presentation, a general overview of the USGS FEWS NET activities in Africa was given. It was shown that 17 countries are monitored using models, ground observations and satellite remote sensing in support of food security. The monitoring process involved a variety of partners, networks and collaborators. All working in horizontal and vertical directions to monitor flood threats to food security, starting with individuals, community, local, national, regional and international levels.

3.2 The various data sets used in hydrologic forecasting modelling were presented starting with rainfall as the main driving force for the rainfall runoff formation process. A satellite derived rainfall estimate or quantitative precipitation estimate (QPE) developed by NOAA/CPC for the FEWS projects and utilizes METEOSAT satellite, SSM/I, AMSU/A and WMO GTS ground observational network were presented. The USGS FEWS Geospatial Stream Flow Model (GeoSFM) was outlined and categorized a semi-distributed physically based hydrologic forecasting model was presented. The model-forecasting component uses a Mesoscale weather model (MM5) forecasts to generate a three days lead-time forecast that will enable evacuation activities during response. The model derives its parameters from global/continental data sets derived by EROS data center and all available at a public domain. These include: A one square kilometer digital elevation and a land use land cover data, the FAO digital soil map of the world at a scale of 1:5,000,000, a global evapotranspiration data set derived using the well motivated Penman-Monteith and a global climatic data set that come from the NOAA GDAS systems at 6 hour interval. The evapotranspiration data together with the NOAA RFE form the model forcing functions.

3.3 For ease of use, the model was interfaced with a Geographic Information System (GIS) within Arc View GIS for model data preprocessing and post processing. The model operates on sub-basin units ranging from 500 – 1000 Km^2. The model surface routing process is based on a geomorphologic unit hydrograph borrowed from Maidment (1993) and the river routing component uses the Muskingum-Cunge equation. The newer version of the model includes different option for excess runoff computation (losses), water balance calculation and routing. A web dissemination methodology that utilizes flood frequency analysis was presented. The outputs are flood risk maps for sub-basins and flood hydrographs in their historical context at certain locations.

3.4 In flood monitoring it was demonstrated that various flood-monitoring products at continental scale are available. These include daily surface runoff derived using a loss method and compared to their historical values, daily and decadal soil moisture, daily and decadal basin excess rainfall maps which indicate the possibility of flooding and a colour coded map for the basins is displayed for each of these parameters. These products are disseminated through the Africa Data Dissemination web page and are also available on request (http://edcintl.cr.usgs.gov/adds/imgbrowses1.php?pass=1). Web sites for model process monitoring are available for the horn of Africa, Southern Africa and Madagascar (see links below) respectively.

http://gisdata.usgs.net/gh_floods/ghamap
http://gisdata.usgs.net/sa_floods/
http://gisdata.usgs.net/moz_floods/madmap/

3.5 With NOAA/CPC, NASA/GSFC, USDA/FAS/PECAD, USAID and FEW NET Chemonics together with the USGS field scientists, USGS conducts a weekly Africa Weather Hazard Assessment (AWHA) net meeting and teleconference to monitor crop and flood in support of food security. The meeting comes up with hazard polygons that are disseminated to the decision makers at USAID and other response agencies in Africa, Afghanistan and Central America. Also USGS issue regular flood advisories and ad hoc flood updates for flood prone basins in the monitoring regions of Africa (East, South and West Africa). All the monitoring and forecasting processes are packaged into national and regional reports/bulletins that feed the decision making process in support of the early warning activities.

3.6 To ensure sustainability of these activities, USGS through its field scientists conducts regular capacity building and training workshop to the countries monitored by the FEWS NET activities in Africa, Central America and Afghanistan. It was shown that, to date more than 500 personnel were trained in the use and implementation of GIS and remote sensing products and stream flow and crop models in support of food security. Financial support in terms of hardware and software is provided to some of the countries through either research institutions or government offices. More details are provided in the Mozambique experience presentation.

Flood Warning System for the Limpopo River in Mozambique

3.7 Mr Hussein Gadain also made a presentation on a Flood Warning System for the Limpopo River in Mozambique. Two devastating floods occurred in Mozambique, in 2000 and 2001 respectively. The USGS data and techniques described above were used to implement a flood early warning system for the Limpopo basin in Mozambique. The very early process started with creation of the data necessary for the system. Production of QPE is done in house in collaboration with the Mozambique meteorological service. More rain gauges were added to the RFE routine to enhance the quality of the product since there was only one rain station that reports to the GTS in the lower Limpopo. This had solved the problem of the delay in the QPE by one or two days. The cyclone monitoring system was also improved. The system developed comprised two components, a flood forecasting model was deployed based on the QPE and QPF data, river gauge from the upstream river system and the GeoSFM forecasting model, and a mapping component that established a finer terrain data of 90 m spatial resolution necessary for the identification of flood inundated areas to be used in conjunction with the forecasted river levels. The main objective of this part was to determine which localities are at risk of flooding given forecast river levels and the location of safe zones to which affected residents should move in order to avoid loss of life and property.

3.8 New rating curves were also established to convert the forecasted discharges into river eights for warning generation. Three flood warning levels were established based on a referenced gauge for each district in the lower Limpopo. Two types of flood warning message were generated, these are:

- General Warnings
  - To inform residents of events 3 to 7 days upstream
  - General Information about heavy rainfall, high river levels or the condition of dams in neighbouring countries
  - Advice on preparatory measures to take
- Alerts
  - To inform residents of specific risks of flooding
  - Includes forecasts of river levels for the next 3 days
  - Names of cities and villages within the risk zones
  - Names of safe locations

3.9 Also, an atlas was created for the whole of Mozambique with the aim of providing integrated data, analysis and maps for individuals and organizations directly involved in preparing for and responding to: FLOODS, CYCLONES, DROUGHTS, and other disasters in the Limpopo Basin of Mozambique.

3.10 To increase awareness the flood forecasting system sponsorship of a journalist training course on reporting disasters, an organized media study tour of Cabora Bassa Dam and Southern

Africa Climate Outlook Forum, tours of Kariba and Cabora Bassa dams on the Zambezi for disaster managers and increased public awareness of cyclone warning categories were initiated.

3.11 Status of the USGS Flood Forecasting System:

- o Full Flood Warning System with Flood Maps operation in the Limpopo Basin in Mozambique
- o Daily flow forecasting and sub-basin flood watch systems in several basins in Southern Africa and the Greater Horn of Africa (GHA)
- o Rainfall estimation being applied in Africa, Central America, South East Asia, Afghanistan
- o Modeling possibilities being discussed with Mekong River Commission and the National Weather Service, Office of Hydrology – a hybrid system with NWSRFS

4. European Flood Forecasting System (EFFS)

4.1 Mr Paolo Reggiani outlined aspects of the EFFS. The EEFS constitutes an open-architecture operational platform for incorporating, interlinking and running various hydrological and hydraulic models to produce discharge forecasts at different locations throughout European river basins.

4.2 The forecasts are driven by numerical weather prediction products of various types and supplied by different European meteorological agencies. The discharge forecasts are based on 10-day ahead deterministic and ensemble predictions with a spatial resolution of 75x75 km and 150x150 km, respectively. Optionally the global model outputs are downscaled to higher spatial resolution via a High Resolution Local Area Models (HIRLAM). The spatial window of the HIRLAM is centred over Europe, forecast lead-time limited to 48-72 hours. The high-resolution local area models are initialised from the global ECMWF global model and have a spatial resolution of 7 x 7 km. The HIRLAM models in EFFS are operated by the German Weather service and by the Danish Meteorological Institute. The high-resolution models are used to better capture effects of horizontal variations on numerical weather predictions. This includes in particular pronounced topographic effects in mountainous regions (e.g. Alps), for which coarser models have shown to under-predict precipitation. Within EFFS it has also been experimented with mini-ensembles (5 members) of high-resolution local areas models, provided by the Danish Meteorological institute.

4.3 The EFFS system is an open platform system, allowing inclusion of particular hydrological models that are currently used operationally throughout Europe. Among those available are the HBV model implemented for the river Rhine and the TOPKAPI model used for the river Po. The output of the hydrological model can be restricted to various sub-basins of a watershed, modelling lateral inflow into the principal river system, e.g. the river Rhine. The actual routing along the main river is performed with the Delft Hydraulics Sobek 1D Saint-Venant model, which accounts for diffusive (backwater) effects induced by presence of engineering structures.

4.4 The various hydrological and hydraulic models are updated over a 14 day window preceding the beginning of the forecast. Over this period data assimilation is carried out on historical gauged records that are stored in the system database, thus creating optimal starting conditions for the forecast. The updating requires the system database to be kept constantly up to date via on-line access to the most recently recorded discharge and water level data in the basins.

4.5 Once the forecast is calculated, post-processing can be carried out and the information prepared into a suitable format ready for dissemination to end-users.

5. International Flood Network (IFNET)

5.1 Mr Akira Sasaki reported on the activities being undertaken in IFNET. Floods are undoubtedly the most devastating natural disasters striking numerous regions in the world each year. During the last century, the trend in flood damages from both social and economical viewpoints has critically increased as a consequence of the increasing frequency of heavy rain, changes in upstream land use and continuous concentration of population and assets in flood prone areas. At local and country levels great initiatives have been devoted to implement appropriate countermeasures aiming to alleviate the persistent threats of water-related disasters. These initiatives undoubtedly combine successful mechanisms and measures that can be of great social and economic benefit to the international community if an ideal mechanism to acquire the knowledge and combine the efforts can be initiated.

5.2 To contribute to the enhancement of international cooperation in flood management issues, the Ministry of Land, Infrastructure and Transport, Japan (MLIT) represented by the Water in Rivers Secretariat, Infrastructure Development Institute (IDI), together with other international key partner organizations, have launched the International Flood Network (IFNET). IFNET has been established with the aim of creating a sound mechanism to mobilize the international community and to serve as a platform within which all organizations and individuals with appropriate qualification in flood management issues can exchange information and experiences and seek partnership to improve the effectiveness of their individual programmes and actions. In other words, through a sound international partnership IFNET has four objectives:

(a) to help break the vicious circle of flood and poverty,
(b) to contribute to economic stability by improving the coordination and effectiveness of measures
(c) to manage flood and reduce the loss of life and property damages, and
(d) to assist developing countries to achieve sustainable development.

5.3 With this in mind, IFNET programmes support the development of a Global Flood Alert System (GFAS) to assist developing countries improve their flood preparedness and enhance local flood control and mitigation measures. GFAS is being developed to provide support to national meteorological organizations in each country for flood alert services and convey information pertaining to heavy rainfall in the upper reaches of rivers where telemeters and observation data do not exist. The GFAS system is being developed based on the Global Precipitation Measurement (GPM) produced after the joint project between JAXA Japan and NASA USA. The global accumulated rainfall data are processed to produce, amongst other data, a 3-hourly global rainfall maps and numerical weather prediction. The precipitation data measured on the surface of the earth at local river basins will be used as calibration data in this process. The 3-hour precipitation map produced by JAXA will be delivered immediately online via Internet to IFNET Global Alert System where further processing based on local geographic and topographic information such critical rainfall returns periods will be pioneered. If the processed data results in an exceeding probability of the recorded critical value, a flood alert is automatically issued to organizations in charge of meteorology and disaster prevention of the concerned country. It is believed that an international cooperation within IFNET and an endorsement of the GFAS project will undoubtedly enhance the ongoing initiatives around the world to alleviate the threat of flood damages and ensure further local, regional and international sustainability.

ANNEX C

SYSTEM NAME		USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
Quantitative Precipitation Estimation (QPE)	Is this QPE part of the methodology?	Yes	Yes	Yes	Yes	Yes	Yes
	Method (describe briefly)	NOAA CPL based on the GPI algorithm utilizing CCD and ground station data from WMO GTS	Currently GOES-8 IR – NESOIS Radar / IR Regressium + gauge merged product – HRC State Estimator, + radar data in Panama (This for Central America). In general, merged satellite, gauge product (+ radar where available).	Daily rainfall records from climatic stations, synoptic stations	Observation by TRMM data	The objective analysis of the precipitation fields observed using the land-based meteorological stations.	The objective analysis of the precipitation fields observed using the land-based meteorological stations.
	Rainfall inputs	Daily rain gauges	Alert gauges, Coop gauges		Automatic	Land-based meteorological stations	Land-based meteorological stations
	Remotely sensed data	CCD, SSM/I, AMSU/A	GOES – 8 currently	No	Precipitation	Satellite Data	Satellite Data
	Time step	daily	hourly	Data are on either hourly or daily time step	3 hours	3-6 hour (24 h – total sums of precipitation)	3-6 hour (24 h – total sums of precipitation)
	Spatial Resolution	7.6 km	4 km	The spatial resolution depends on the density of the particular data collection network of each member country.	Normal: 30 km x 30 km Max: 4 km x 4 km	$2.5 \mathrm{x} 2.5^{o}$	$2.5 \mathrm{x} 2.5^{o}$

	SYSTEM NAME	USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
	Database (historical available)	Daily 1995 – present to running back to 1989; ……… some to running back to 1982	About 10 years	Yes, supplied by the global runoff data centre (GRDC)	Yes (confidential)	Yes	Yes
	Verification Performed and how	Preliminary verification carried through a workshop	System not yet completed – validation planned for selected events	The new data are validated. Missing values are filled in by interpolation. Rates of rise of discharge are tested	Test run is ongoing. Seeking for the partner organizations, once find them, activate the system (proto type) ASAP.	No comment	No Comment
Quantitative Precipitation Forecasting (QPF)	Is QPF part of the methodology?	Yes	No – can easily be added – this element not funded under current project	Yes		Yes	Yes
	Method	US Air force Mesoscale Model (Mm5)	N/A	Numerical weather prediction of three European Meteorological offices (DWD, ECMWF, DMI)		The calculation of convection – Kuo-type scheme; surface processes (land surface temperature, soil moisture and snow depth) are predicted, SST is fixed; precipitation predicted on the base of the microphysical processes in liquid and mixed phase clouds.	The regional non adiabatic model in σ - system of coordinates for the territory including Europe, all Russia, including the Far East. The calculation of radiating streams of seen, infra-red and long-wave radiations, blocks of the decision of the equation of thermal balance and block of the ground sublayer characteristics

SYSTEM NAME		USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
							calculation, the evolutionary equation for energy of turbulent pulsations are included in this model. The regional model has 30 settlement levels on a vertical.
	Lead time (Forecast horizon)	3 days	N/A	10 days (low resolution) 48 hours (German local model) 78 hrs (Danish Meteo high resolution model = HIRLAM)		1-10 days	From 6 to 48h
	Time step	6 hours	N/A	6 hours (EPS, deterministic forecast) 1 hour (High resolution models, DMI, DWD)		24h	6h
	Spatial Resolution	45 km	N/A	Deterministic forecast: 70 x 70 km Ensemble prediction system: 150 x 150 km Hirlam/Local Model: 7 x 7 km (high resolution)		150x150 km, 28σ-levels	70x70 km
	Database available of gridded output (Yes / No)	Yes	N/A	Yes		Yes	Yes
	Verification performed and how	No	N/A	Reanalysis of past events and		Yes. On the base of official operational	Yes. On the base of official operational

SYSTEM NAME		USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
				verification on cumulated measurement		technology (1 time per month) – Hanssen and Kuipers (HK) discriminant for forecasts and for inertia	technology (1 time per month) - Hanssen and Kuipers (HK) discriminant for forecasts and for inertia
Ensemble	Are Ensemble Forecasts used?	No	No – currently QPE only. Could use ensemble forecasts	Yes	No	Yes (under testing) Valet analysis	Yes (under testing) Valet Analysis
	Lead time (Forecast horizon)	N/A	N/A	10 days (low resolution) 72 hrs (Hirlam models)	N/A	From 1 to 4 months	From 1 to 4 months
	Resolution	N/A	N/A	N/A	N/A		
	Number in ensemble	N/A	N/A	1) 50 + 1 control forecast (ECMWF EPS) 2) 5 + 1 control forecast (7 x 7 km Hirlam)	N/A		
	Database of gridded output (Yes / No)	N/A	N/A	Yes	N/A	No	No
	Verification performed and how	N/A	N/A	Reanalysis of past events and verification on cumulative precipitation records	N/A	Yes. On the base of official operational technology (1 time per month) Yes. On the base of official	Yes. On the base of official operational technology (1 time per month) Yes. On the base of official

	SYSTEM NAME	USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
						operational technology (1 time per month) - Bias, RMSE, CORR, HK	operational technology (1 time per month) - Bias, RMSE, CORR, HK
Hydrological Modelling	Rainfall-Runoff Model	USGS Geo-spatial stream flow model	Threshold runoff merged with soil moisture accounting	EFFS allows to include generic modes, among which HBV, TOPKAPI, Sacramento, Xinanjiang and others)		The conceptual model for plain river	The conceptual model for plain river
	Routing techniques	Surface runoff routing – geomorphologic UH Channel routing 3 methods (Muskingm – Cunge and others)	Implicit in threshold runoff	Sobek river (1-D Saint Venent) Muskingum – Cunge routing scheme		The joint decision of the system of the equations of movement and indissolubility, the approached decision of the equations of water and thermal balance for basins.	Calculation of receipt and expenditure of water in various high-altitude zones on the basis of the equation of thermal balance; calculation of moving of water on a surface of a basin and in the river channel.
	Input data required and resolution	Terrain 1 km Land use, land cover 1 km Soil 1:5,000,000	Digital elevation data, land use / land cover, soils, catchment geometry (as available), stream co-ordinates (as available)	Rainfall, temperature (snowmelt) Q/H for model updating / data assimilation		Standard operational data of Hydrometeorological observation and forecasts such characteristics as: - air temperature; - temperature of dew point; - the wind velocity; - cloudness; - precipitation; - water levels, water discharges, snow water	Standard operational data of Hydrometeorological observation and forecasts such characteristics as: - air temperature; - temperature of dew point; - the wind velocity; - cloudness; - precipitation; - water levels, water discharges, snow water

SYSTEM NAME		USGS	FFTPP	European EFFS	IFNET	CHy Expert Global Model	CHy Expert Regional Model
Model Component	**Descriptor**						
						equivalent (the observed data)	equivalent (the observed data)
	Resolution of Forecast Product	Sub-basin	100-300 km^2 catchments (can be higher resolution with higher resolution terrain elevation / precipitation data)	Arbitrary basins in Europe		The forecasts issue for each item (non grid)	The forecasts issue for each item (non grid)
	Time step	Daily	1 – 3 – 6 – 12 – 24 hours	Hourly, daily (depending on input data resolution)		12-24 h	12-24 h
	Lead time (Forecast Horizon)	3 days	Currently now cast	Up to 10 days Reliability decreases after 6 days due to high uncertainty		1-5 days	From 1-5 days to 6 months
	Products / outputs (i.e probabilistic / ensemble, sole determinist, types of products….)	- deterministic downscaled to probabilistic; - daily soil moisture at sub-basin level; - daily stream flow; - daily river depth; - Inundated areas; - Web dissemination	Flash flood guidance, flash flood severity, rainfall estimate (Gridded or catchment), soil moisture deficit (1000 km^2 basins)	Ensemble and deterministic forecasts of stage and discharge. Inundation isocrones and maps produced with Sobek 2 - D		Deterministic forecasts.	Deterministic forecasts.

ANNEX D

SHORT-TERM HYDROLOGICAL FORECASTING
SWOT ANALYSIS

STRENGTHS

Quantitative Precipitation Estimation (QPE)

- Identified hydrological need for QPE for a variety of purposes,
- Better access to rain gauge data through the GTS,
- Increasing availability of observational data – radar data, satellite data and model output,
- Increasing capability to estimate QPE accurately,
- Newer radar and satellite capabilities.

Quantitative Precipitation Forecasting (QPF)

- Increasing demand for QPF across a range of disciplines,
- Increased capability of meteorologists to better model the atmosphere,
- Significant advances in meteorological science have lead to improved forecasting capabilities,
- Higher resolution modelling is now possible.

Hydrological Modelling

- Water has a high profile nationally and internationally,
- High demand for forecast model output for a range of purposes,
- Good tools now available (but could be better at lower time increments),
- The components for improved services are there, however, the linkages need improving.

WEAKNESSES

QPE

- Scarcity of rain gauges in many areas,
- Derivation of QPE/QPF is a complex activity,
- Lack of easy access to radar and satellite data,
- Calibration techniques for radar and satellite derived data are uncertain – still too many errors,
- A good composite QPE estimate capability is not available,
- Methodologies are not well packaged,
- Radars not necessarily geared to estimate rainfall for hydrological modelling purposes,
- Lack of skills/expertise in radar and satellite data analysis,
- Rainfall estimation in mountainous areas is still difficult.

QPF

- Hydrological groups not benefiting enough at the present,
- Access to model output is difficult (large volumes and mixed formats),
- Models are changing and it is difficult to keep pace,

- Current activities are “Developed World” focussed,
- Higher resolution tools are required,
- Many methodologies are still experimental.

Hydrological Modelling

- Training is not available in all regions,
- Models not always suitable for new inputs,
- Competition between modellers can restrict developments,
- Modellers can be too focussed on their own activities,
- Many groups are not keen to change,
- Systems to make the linkages are not available in all cases.

OPPORTUNITIES

QPE

- Strong need for QPE in a range of areas – Agrometeorology, pastural products,
- Unified format for satellite and rainfall data would be of great assistance,
- Global, real-time maps of QPE
- QPE is required for verification of QPF,
- QPE estimation should support the establishment and continuation of ground stations.
- Improved radar and satellite capabilities.

QPF

- Hydrological need for the products,
- Create a database for easier access to model output,
- Hydrologists can/could use NWP output and run the models ourselves,
- Work more closely with NMS’s and contribute to product development,
- Input to risk management studies.

Hydrological Modelling

- Improved rainfall fields and other related information,
- Benefits of sharing experience and capabilities,
- Increasing demands for hydrological products.

THREATS

QPE

- Possible threat to reduce ground stations,
- Inability to keep up with evolving technology and calibration requirements,
- Possible impacts on the role and responsibilities of NMS’s and NHS’s (needs to recognised and addressed),
- Improvements to QPF become such that QPE not required.

QPF

- Constantly changing models (hard to keep up with),
- Increased financial pressure on NMS's to reduce networks, eg radio sondes,
- Meteorologists could take on the role of hydrological modelling in NWP's,
- Hydrologist could lose touch with meteorologists,
- Not all NWP models have operational status.

Hydrological Modelling

- Some groups not willing to change methodologies,
- Increased dependence on hydrological and meteorological data during flood events,
- Insufficient R&D resources,
- Cyclic nature of floods and droughts,
- Must continue to verify hydrological models,
- Lack of or difficult access to meteorological data in future.