WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

EXPERT MEETING ON VERY SHORT-RANGE FORECASTING (EM-VSRF)

GENEVA, SWITZERLAND, 21-23 MARCH 2011

FINAL REPORT

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EXECUTIVE SUMMARY

The Expert Meeting on Very Short-Range Forecasting (EM-VSRF) was held in Geneva, Switzerland, from 21 to 23 March 2011.

The meeting reviewed the outcomes of its previous meeting (Toulouse, France, November 2007), including its recommendations and the table of possible blending approaches with model and observational data combinations for very short-range forecasting.

The meeting also reviewed recent developments in possible blending approaches of combination of NWP and observational data for very short-range forecasting and discussed possible practical applications, whether in existing projects (e.g. SWFDP, flash flood forecasting regional projects) or as an independent action.

The meeting developed recommendations and guidelines on the way forward and future work on very short-range forecasting. In particular, the meeting agreed that very short-range forecasting should be considered/addressed as an end-to-end process, covering the following aspects: (i) in situ and remote-sensed observations; (ii) NWP, including verification aspects; (iii) post-processing, including blending approaches and extrapolation; (iv) synergies with hydrology; and (v) interactions with end-users. The meeting also agreed that education and training issues are relevant in all stages of the very short-range forecasting system, as well as visualization tools.

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. OPENING

1.1 The Expert Meeting on Very Short-Range Forecasting was opened by the Chairperson of the CBS OPAG on Data processing and Forecasting Systems (DPFS), Mr Bernard Strauss (France), at 09.30 hours, on Monday, 21 March 2011, at the WMO Headquarters, in Geneva, Switzerland. Mr Strauss welcomed participants to the meeting, and introduced Dr Geoffrey Love, Director of the WMO Weather and Disaster Risk Reduction Services Department (WDS), to address the meeting.

1.2 Dr Love, on behalf of the WMO Secretary-General, Mr Michel Jarraud, welcomed all participants to the meeting and to Geneva. He recalled the recent environmental emergencies that inflicted damage to homes, livelihoods and infrastructure in many parts of the State of Queensland (Australia) and in Rio de Janeiro (Brazil), as a result of flash floods. Dr Love highlighted the importance of the application of NWP systems in very short-range forecasting (up to 12 hours), with the view to realizing greater benefits from NWP system developments, integrating real-time observational data for tracking and forecasting of hazards. In particular, he stressed the need for guidance for very short-range forecasting, in particular in the application of possible blending approaches (with model and observational data combinations for very short-range forecasting), for example in relation to SWFDP projects.

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda

2.1.1 The meeting adopted the provisional agenda, as provided in Annex I.

2.2 Working arrangements

2.2.1 The meeting was invited to nominate from among the participants a chairperson to conduct the business of the workshop. Mr Pierre Eckert (MeteoSwiss) was unanimously elected to act as the chairperson for this meeting.

2.2.2 All documents submitted for the meeting are referenced and hyperlinked in the Documentation Plan (INF. 1), which had been posted on the WMO web site at:

http://www.wmo.int/pages/prog/www/DPFS/Meetings/EM-VSRF_Geneva2011/EM-VSRF_DocPlan.html

2.2.3 The participants agreed its hours of work and other practical arrangements for the meeting, including the tentative work programme. Participants briefly introduced themselves, to facilitate interactions throughout the meeting. The list of participants in the meeting is provided in Annex II.

3. INTRODUCTION, REVIEW, SCOPING

3.1 Review of the outcomes of the previous meeting (Toulouse, November 2007)

3.1.1 Recalling that forecasting in the very short-range is defined in the *Manual on the Global Data-Processing and Forecasting System (GDPFS)* (WMO-No. 485) as forecasts within 12 hours of the present, which includes "nowcasting" (defined as forecasts within 2 hours of the present), the meeting reviewed the major outcomes of its previous meeting (November 2007), including its recommendations and the table of possible blending approaches with model and observational data combinations for very short-range forecasting (see Annex III).

3.1.2 The meeting noted that, at its previous meeting (November 2007), input and discussions included the status and GDPFS activities in WMO Regions, primarily on high-resolution limited area models (LAMs), used in conjunction with available observational data, as well as relevant activities of and issues identified by the World Weather Research Programme (WWRP) in relation to nowcasting. Noting that there is a diversity of techniques and systems developed and implemented by WMO Members, the 2007 meeting agreed that demonstration projects (such as the CBS Severe Weather Forecasting Demonstration Project (SWFDP)) could represent opportunities for comparing new technologies and techniques, as well as those for operational trials, to facilitate rapid and successful implementation, accounting for regional contexts and capacities (e.g. developing countries).

3.2 Report on the outcomes of CBS-Ext.(10) related to Very Short-Range Forecasting (VSRF)

3.2.1 The meeting was presented with a report on the outcomes of CBS-Ext.(10) related to very short-range forecasting. Recalling that a suitable blending of the use of real-time observational data sets and nowcasting methods, with high-resolution NWP outputs is possible to address this forecasting range (the first 12 hours), CBS-Ext.(10) had agreed that the table of possible blending approaches (see Annex III), should be further developed or applied, for example in relation to SWFDP projects where clear requirements have been identified, for example in guidance to flash flood forecasting.

3.2.2 The meeting noted that, among the main challenges for the SWFDP, is the need for very short-range forecasting (including the first 12 hours) tools, especially to address the rapid onset of localized severe thunderstorms that produce heavy precipitation and strong winds, in the absence of adequate real-time observational networks, especially in absence of weather radar coverage. In this context, the meeting noted that, following the outcome of the first phase of the SWFDP in Southeast Africa (in 2008), the RSMC Pretoria Web site has incorporated Eumetsat/MSG derived products for nowcasting purposes. Detailed information is provided under agenda item 5.1.

3.2.3 The meeting was informed that the CBS Steering Group for the SWFDP has been coordinating with the CBS Expert Team on Satellite Utilization and Products (ET-SUP), to explore collaboration related to training, satellite information (data and products) and dissemination mechanisms to support the SWFDP. In addition, WMO is providing input to the annual meeting of the Coordination Group on Meteorological Satellites (CGMS), in relation to SWFDP developments, suggesting possible collaboration on improved uptake by forecasting centres of satellite products and on satellite dissemination of SWFDP-needed products.

3.3 Scope of the meeting

3.3.1 Based on the information provided under the previous agenda items, the meeting agreed on the general scope and aims of this meeting. The goal of the meeting is to transfer the knowledge into practical applications focusing on developing countries. The applications (through knowledge transfer and/or capacity building) can be included in an existing demonstration project (e.g. SWFDP) or an independent action can be proposed. The meeting agreed that very short-range forecasting should be addressed as an end-to-end process, with the engagement of forecasters and end-users.

3.3.2 The meeting agreed to review recent developments in possible blending approaches of combination of NWP and observational data for very short-range forecasting (under agenda item 4), and to discuss (under agenda item 5) possible practical applications (whether in existing projects or as an independent action) of:

- The use of frequent and recent observations in the assimilation of NWP;
- Blending methods of NWP output and observations;
- Post-processing of NWP outputs.

4. DEVELOPMENTS IN APPROACHES OF COMBINATION OF NWP AND OBSERVATIONAL DATA FOR VSRF

4.1 The meeting was informed of the recent developments in possible blending approaches of combination of NWP and observational data for very short-range forecasting, based on the reports by Mr Paolo Ambrosetti (MeteoSwiss, Switzerland), Mr Donald Talbot (Canadian Meteorological Centre (CMC), Canada), Dr Baode Chen (Shanghai Meteorological Bureau (SMB), China), and Jean-Marie Carrière (Météo-France, France). Full reports and PowerPoint presentations are available on the WMO web site at http://www.wmo.int/pages/prog/www/DPFS/Meetings/EM-VSRF_Geneva2011/EM-VSRF_DocPlan.html.

4.2 The meeting was presented with blending techniques in very short-range forecasting, including examples under operational constraints. The meeting noted that end-user requirements include high time and space resolution of relevant parameters to support decision-making processes (gridded values are often necessary). Data sources include: weather radar; geostationary satellites; automatic ground stations; lightning detection; NWP (direct model output or with some kind of post-processing (e.g. MOS, KF, etc.)); high resolution topographical information (Digital Terrain Model (DTM)); and climatology, as mean values/fields or stratified by weather classification. The meeting noted that the constraints associated with the use each of these data sources for very short-range forecasting.

4.3 The meeting agreed that very short-range forecasting should be considered as an end-to-end system, including in situ and remote-sensed observations; NWP; post-processing; and interactions with end-users. The meeting also agreed that any end-to-end system should take into account data source constraints, in order to optimize the forecasting process and to provide timely all relevant information to the end users for their decision-making processes and actions.

4.4 The meeting repeatedly stressed the importance of availability and timely exchange of observational data including in-situ meteorological observations and retrievals of observational data, and parameters (e.g. estimates of instability) computed from data acquired from satellite-based systems, aircraft (i.e. AMDAR), lightning and radar (where available). Noting that many required datasets are not exchanged on the WIS, the meeting encouraged the open exchange among Members of such data for use in real-time severe weather forecasting and warning programmes.

4.5 Recognizing that, in the initial range of the forecast, the forecasting process depends heavily on systems that process observational data and analyses, and extrapolated into the immediate future, the meeting agreed that the use of these many recent data would provide frequent analyses as input to models, which could run freely (without blending) afterwards.

4.6 The meeting noted that many National Meteorological Centres (NMCs), some in conjunction with other national agencies, have implemented and continue to develop high-resolution (10 km resolution, or less) Limited Area Models (LAMs) that are relevant to very short-range forecasting.

4.7 The meeting noted that the “blending” of high-resolution NWP outputs with products based on observations is carried out, either integrated through a processing/forecasting system (use of frequent and recent observations in the assimilation of NWP to increase lead time in forecasting, integrating all types of data - e.g. INCA), or performed subjectively by forecasters (conceptual models). The meeting agreed that NWP systems should as much as possible assimilate available observational data to improve their predictions, while further post-processing of NWP outputs with additional information could further improve or “downscale” these outputs to specific locations or applications (e.g. flood forecasting). Such post-processing could include statistical methods (e.g. KF, MOS) – adaptive post-processing, or a “specialized” 2-dimensional surface model (e.g. CaLDAS) that combines NWP outputs with additional latest in-situ surface observations, soil surface conditions and high-resolution topographical information – dynamic post-processing.

4.8 The meeting noted that forecasters and end-users often find an interest in knowing the uncertainty that is associated with the forecast, or the probability of occurrence of the forecast scenario, especially in the case of severe weather forecasts where important decisions have to be made. The meeting noted that, to this end, a small number of NMCs have been implementing ensemble prediction techniques, which are useful and can be applied to very short-range forecasting, depending on the computer power available. In particular, the Short-Term Ensemble Prediction System (STEPS), a precipitation nowcasting system, characterizes uncertainty due to advection and the more stochastic evolution of precipitation at small scales.

4.9 Noting that there is a diversity of very short-range forecasting systems and techniques developed and implemented by WMO Members and that there is a need to exchange such systems and share knowledge, the meeting discussed the portability of such systems and techniques, focusing on developing countries. The meeting agreed to further address this issue under agenda item 5.3.

5. PRACTICAL APPLICATIONS AND PROJECTS

5.1 Severe Weather Forecasting Demonstration Project (SWFDP)

5.1.1 Mr Eugene Poolman, chairperson of the Regional Technical Implementation Team (RTIT) of the SWFDP in Southern Africa, provided an overview of the SWFDP in Southern Africa. The meeting noted that SWFDP aims to contribute to capacity-building and to help developing countries to have available and implement the best possible use of existing NWP products for improving warnings of hazardous weather conditions and weather-related hazards. At a very early stage of the SWFDP implementation, while the SWFDP was able to improve the lead-time of alerting of severe weather in the medium-range, some deficiencies have also been identified, such as tools for forecasting the rapid onset (i.e. nowcasting tools) of localized severe thunderstorms, heavy precipitation and strong winds. Noting the very limited weather radar coverage (at that time, only South Africa and Botswana had operational radar systems), and recognizing that satellite data processing systems and products represent powerful tools for forecasting in the very short-range, the meeting agreed that NMHSs in developing and Least Developing Countries (where weather radars are few or non-existent) should make maximum use of such products and systems.

5.1.2 In this context, the meeting noted that in 2008, following the outcome of the first phase of the SWFDP (southeast Africa), the RSMC Pretoria Web site has incorporated MSG/Unified Model combined products prepared at RSMC Pretoria that estimate cumulative rainfall amounts (e.g. the "hydro-estimator") and diagnostic products (e.g. the "global instability index "GII"). They are primarily used for tracking and "nowcasting" convective storms, especially those of rapid onset and with the potential to develop into severe thunderstorms. The meeting also noted that new products are envisaged to be developed and incorporated on the RSMC Pretoria Web site targeting improved very short-range forecasting, including nowcasting. The meeting agreed that the SWFDP provides an appropriate framework for introducing such new tools and techniques, and that education and training is a critical component. Noting that there is a diversity of post-processing systems developed and implemented by WMO Members, the meeting recommended the development of a post-processing "tool-kit" that NMHSs could implement, in whole or in part, that would enable optimal use of existing very short-range forecasting systems.

5.1.3 In addition, the meeting noted that all participating NMHSs have received training on the use of MSG receive stations (equipment which had been provided through the "PUMA" project to all African countries to give them access to the 12 channels of MSG and the associated wide range of products), and on the suitable software application that carries out local image data processing. However, it was noted that not all participating NMHSs have functioning MSG receiving stations due to maintenance/sustainability constraints, and the WMO Regional Programme for Africa in collaboration with the WMO Space Programme are addressing this issue with Eumetsat. Noting that most of the participating NMHSs have limited resources, required to maintain such systems, the meeting acknowledged the critical role of the RSMCs in providing products to NMHSs in the region, following the model of the SWFDP.

5.1.4 Mr Poolman informed the meeting that the Southern African Regional Flash Flood Guidance (SARFFG) project is one of the sub-regional projects of the WMO's global FFGS programme. The meeting noted that the operational system will be rolled out in 2011. Seven countries in Southern Africa (Namibia, Botswana, Mozambique, Zimbabwe, Zambia, Malawi and South Africa), a regional centre (RSMC Pretoria) and a global centre would participate in the SARFFG through a mechanism of cascading of information to the NMHSs. SARFFG involves a combination of regular hydrological modelling for small catchments over the entire domain with real time precipitation information from satellites to determine catchments with the potential of experiencing flash floods. The meeting agreed that similar to SWFDP, the SARFFG would allow forecasters in NMHSs to use the information received from the global and regional centres to issue nowcast information on potential flood to the disaster management structures (end-users) in their countries. The meeting expressed the importance of developing an excellent collaboration between weather forecasters and hydrologists, and between weather forecasters and disaster managers in each country for the success implementation of the SARFFG. Recognizing the similarities between the SWFDP activities and the SARFFG system, the meeting recommended synergy between the cascading frameworks of SWFDP and the SARFFG to maximize existing structures in the region.

5.2 Flash flood forecasting

5.2.1 Mr Paul Davies (Met Office UK) presented an overview of the opportunities in developing a holistic approach to flood forecasting using coupled NWP – Hydrological models and data sharing systems. This approach, underpinned by training and knowledge transfer across the hydrological and meteorological disciplines, should drive forward advancements in flood warning services with lead times of 12 hours or less (flash floods). Complimenting existing guidance and warning systems (Vigilance), any flood guidance and warning services emanating from such coupled systems should enable civil protection and the public be better prepared for a potential of flash flooding. This in turn should reduce hydro-meteorological impacts and avoidance costs.

5.2.2 The meeting noted that forecasting rainfall at hydrological important scales is becoming a real possibility. Such scales are now being resolved by the new generation of observation systems, and weather models coming to use, and it is expected to give increasingly useful forecasts of rainfall and runoff. As a result, flood forecasting and warning systems, which historically have been based on the lack of sufficiently fine scale rainfall information, need to be revisited in the light of the new meteorological capabilities. This is particularly true for flash flooding, where these new capabilities offer the possibility of providing more reliable warnings.

5.2.3 The meeting noted that the WMO is attempting to address operational prediction of flash floods in the 1-6 hour time-range by introducing the Flash Flood Guidance System (FFGS) projects in various developing regions of the world. The FFGS is a hydrometeorological modelling system that predicts the flash flood guidance value for each small river basin based on hydrological conditions, i.e. the rainfall amount needed for a given duration (1, 3 or 6 hours) that may lead to minor flooding in a specific basin. To identify basins where potential flash flooding can occur, forecasters need to provide quantitative forecasts of rainfall amounts expected in the next 1, 3 and 6 hours to compare with the flash flood guidance value for each basin. The meeting recommended that approaches of extrapolation, blending and post-processing be used to provide the required forecasts.

5.2.4 The meeting agreed that rapid advances in modelling has shifted the focus of flood forecasting systems away from the models themselves to an integrated process of integration of multiple sources of observed and forecast data, coupled with multiple models, to provide a more complete picture of possible forecast results. The meeting noted that that there remain issues on how best to couple meteorological and hydrological models, including:

a) Differing scales (temporal and spatial) of the two areas of modelling and difficulties in taking the outputs from the meteorological models into the hydrological models;

b) Realizing the benefit of developing a hierarchical approach to modelling, starting with large sized catchments and moving down to towards smaller (flashy) areas;

c) Continuous updating and improvement of the meteorological models will require new calibration and updating of hydrological models to allow for changed inputs;

d) Although they improve continuously meteorological models still miss the quality of precipitation forecast that is required for accurate flood prediction, in terms of amount, location and timing. Rainfall forecasts are average depths across a full grid square. Downscaling procedures are required and need further development;

e) A quick benefit of this collaboration with hydrology shall be to render a diagnostic chart of soil saturation in helping forecasters in forecasting the severity of flash flood.

5.3 Organization of knowledge transfer

5.3.1 Based on discussions under the previous agenda items, the meeting discussed possible ways of transferring the knowledge into these practical applications and projects, focusing on developing countries. The meeting agreed that:

(a) Established RSMCs should play a key role by providing products and tools for very short-range forecasting to NMHSs in their regions, following the model of the SWFDP.

(b) A post-processing "tool-kit" should be developed, which could be implemented (in whole or in part) by NMHSs. This would enable optimal use of existing post-processing systems for very short-range forecasting.

(c) Training materials on how to use, interpret and improve very short-range forecasting tools (tuned to particular regions) should be developed, including showcases and examples on strengths and weaknesses of the various systems.

(d) User-oriented post-processing tools should be developed in collaboration with the end-users. These include: the development of Standard Operating Procedures (SOPs), the definition of thresholds, etc., in a multi-hazard approach.

(e) Forecasters and hydrologists should work together for developing a holistic approach to flood forecasting using coupled NWP – hydrological models and data sharing systems.

6. DEVELOPING TECHNICAL GUIDANCE ON THE IMPLEMENTATION OF VSRF SYSTEMS, FOCUSED ON DEVELOPING COUNTRIES

6.1 Mr Jean-Marie Carrière, the CBS Rapporteur on Applications of NWP to Severe Weather Forecasting, presented a revised draft document (Doc. 6) entitled: "Guidelines on the use of operational NWP capabilities for severe weather forecasting", which includes the entire forecasting range from nowcasting and the very short-range, to seasonal forecasts. The main purpose is to highlight and improve the recognition of operational NWP technologies for forecasting and production of early warnings of meteorological hazards and other important environmental prediction activities such as for flooding, large fires, or winter environmental conditions. The target audience is mainly NMHSs and users of meteorological services.

6.2 The meeting noted that the first draft was present to its previous meeting (November 2007). The meeting felt that the document is a very good idea, appropriate for promoting the value of NWP systems in many areas of meteorological applications, and that it should be further developed, including addressing application areas (e.g. hydrological forecasting). Noting that there is a diversity of post-processing systems developed and implemented by WMO Members and that there is a need to exchange such systems and share knowledge, the meeting suggested that this document could include more detailed annexes (hyperlinked) containing the information on the various methodologies, their accessibility, and describing what can be realistically implemented in e.g. a developing country. This document, when finalized, should be posted on the WMO Web site as a GDPFS information or guidance document.

6.3 The meeting discussed the possibility of developing of a post-processing “tool-kit” that NMHSs (in particular, the developing countries) could implement, in whole or in part, that would enable optimal use of existing NWP systems and outputs in combination with all other available data or information for very short-range forecasting.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Based on discussions under previous agenda items, the meeting developed recommendations and guidelines on the way forward and future work on very short-range forecasting. In particular, the meeting agreed that very short-range forecasting should be considered/addressed as an end-to-end process, covering the following aspects: (i) in situ and remote-sensed observations; (ii) NWP, including verification aspects; (iii) post-processing, including blending approaches and extrapolation; and (iv) interactions with end-users. The meeting also agreed that education and training issues are relevant in all stages of the very short-range forecasting system, as well as visualization tools. The meeting recommended that more efforts be made on targeting sensitive areas/aspects of this end-to-end process.

In situ and remote-sensed observations

7.2 The meeting stressed the importance of availability and timely (real-time) exchange of observational data including in-situ meteorological observations and retrievals of observational data, and parameters (e.g. estimates of instability) computed from data acquired from satellite-based systems, aircraft (i.e. AMDAR), lightning and radar (where available). Noting that many required data sets are not exchanged on the WIS, the meeting encouraged the open exchange among NMHSs of such data for use in real-time severe weather forecasting and warning programmes. The meeting agreed that this exchange of observational data could follow the model developed within the SWFDP. Noting that the Met Office UK holds a global lightning network, which is available, the meeting recommended NMHSs to make maximum use of such data for very short-range forecasting.

7.3 In addition to synoptic observational data, which are generally available through the WIS, the meeting recognized the importance of non-synoptic observational data for very short-range forecasting. These include meteorological-based observations, as well as other observational systems (e.g. rain and river gauges) are necessary for various applications (e.g. tuning remote-sensed products, post-processing, and validation of NWP outputs). In addition, user data systems could also be incorporated, in order to meet end-user needs for more targeted warnings in the very short-range forecasting. The meeting acknowledged the urgency to resolve the issues of data exchange at a regional level, in order to make improvements on multi-hazard warning systems (e.g. flash flood guidance system).

7.4 While noting that many NMHSs in developing countries do not have operating weather radars and/or national-wide radar coverage to support timely and accurately forecasts and warnings of severe convective in the very short-range forecasting period, the meeting recognized that satellite data processing systems and products represent new and powerful tools for forecasting in this forecast range. It therefore recommended that NMHSs in developing and Least Developed Countries (where weather radars are few or non-existent) to make maximum use of satellite-based products. In addition, noting that the WWRP/CAS Working Group on Nowcasting Research (WGNR) has been focusing on the use of radar-based products for nowcasting, the meeting suggested that the WGNR also address technologies and tools for nowcasting using satellite data processing systems and products.

7.5 While noting the benefits of using real-time satellite-based products in very short-range forecasting, in particular for nowcasting, the meeting recognized that there are difficulties in the uptake of new products into weather forecasting daily routines of the forecasters. It therefore agreed that the SWFDP provides an appropriate model for introducing these new elements, as includes verification and reporting mechanisms, and training aspects.

7.6 While noting that a description of the satellite-based products is provided on satellite operators web sites (e.g. Eumetsat; http://oiswww.eumetsat.org/VLab/html/Satellite_Products.php), the meeting recommended the development of guidelines on how to use and interpret these products at the regional level, taking into account regional and national requirements. These guidelines should be focused on practical use of such products by forecasters.

7.7 The meeting recognized that verification of satellite-based products is important. Noting that some results have been presented for example at Eumetsat workshops, the meeting recommended strengthening the liaison with the WMO Space Programme to facilitate access to these results.

NWP, including verification aspects

7.8 The meeting agreed that high-resolution (10-km resolution, or less) limited area models (LAMs) are very relevant to very short-range forecasting. These allow better representation of the topography, surface characteristics, and dynamical and physical processes, and more frequency of data assimilation (rapid refresh of analysis and forecasts) to take into account the latest observations. The meeting recommended that these NWP systems assimilate as much as possible all available and recent observational data to improve their predictions.

7.9 The meeting noted the significant resources required to maintain NWP systems in operational use and in optimal configuration (boundary conditions, local data assimilation, model tuning and adjustment, and verification). The meeting recommended that established RSMCs could provide NWP products to NMHSs in a region, following the model of the SWFDP.

7.10 The meeting agreed that verification of NWP for severe weather events (object-oriented verification), especially of very high-resolution model outputs is important, and that it is essential to implement an operational verification system to assess performance, particularly in relation to important thresholds of forecast NWP fields, and to monitor and improve the forecasting system. In this respect, the meeting suggested the use of the “Fuzzy” verification techniques. The meeting recommended strengthening collaboration with the WWRP/WGNE Joint Working Group on Forecast Verification Research (JWGFVR) on these matters.

7.11 The meeting agreed that ensemble prediction techniques are useful and can apply to very short-range forecasting. However, it noted the significant resources required to implement such a system, which could be a major constraint for a developing country. In this context, the meeting recommended that whenever possible, the uncertainty associated with the forecast, or the probability of occurrence of the forecast scenario, be communicated to the end-users, especially in case of severe weather forecasts where important decisions have to be made, especially in medium-range lead-times.

Post-processing, including blending approaches and extrapolation

7.12 The meeting agreed that in the initial range of the forecast, the forecasting process depends heavily on systems that process observational data and analyses (radar and satellite products, in-situ surface observations) and extrapolated into the immediate future. The meeting noted that SAF nowcasting (http://www.nwcsaf.org/HD/MainNS.jsp) makes its products and software available for implementation upon request, including recognition and evolution of objects. It also noted that some of the products can be used for early detection of potential development zones. The meeting therefore recommended that these products be implemented at the global and regional levels, within the framework of the SWFDP. Noting that the algorithms may not apply from one satellite data acquisition system to another (i.e. different regions have different satellites, and different instrument and data systems), and the need for tuning products for a specific region, the meeting also recommended further engagement of the WMO Space Programme, and its Expert Team on Satellite Products and Utilization, in the SWFDP, at both the Steering Group of the SWFDP as well as at the Regional Subproject Management Team for each subproject, to advise on these aspects. In addition, the meeting recommended that the activities being implemented in each regional SWFDP subproject be shared among relevant global and regional centres.

7.13 The meeting noted that the “blending” of high-resolution NWP outputs (10-km resolution, or less) with products based on observations is carried out, either integrated through a processing/forecasting system, or performed subjectively by forecasters. The meeting agreed that further post-processing of NWP outputs with additional information could further improve or “downscale” these outputs to specific locations or applications. Such post-processing could include statistical methods (e.g. KF, MOS), indices, or conceptual models, including those combining data from different sources (e.g. INCA, CALDAS).

7.14 Noting that there is a diversity of post-processing systems developed and implemented by WMO Members and that there is a need to exchange such systems and share knowledge, the meeting recommended that the Secretariat combine the information on the various methodologies, which are mostly available through the ‘Annual WMO Technical Progress Report on the GDPFS and related Research Activities on NWP’, and their availability in a single document in order to provide technical and operational guidance on the implementation of very short-range forecasting systems, focused on developing countries. The meeting also recommended the development of a post-processing “tool-kit” that NMHSs could implement, in whole or in part, that would enable optimal use of existing NWP outputs in combination with all other available data or information for forecasting in this time range.

Interaction with end-users

7.15 Noting that the very short-range forecasting systems, like any other system, must be targeted to meet end-user needs, the meeting recommended the involvement of end-users (including the civil protection and disaster management authorities) in the development of user-oriented post-processing tools, including probabilistic forecasts, and standard operating procedures.

7.16 The meeting stressed that forecasters must be aware of the needs of end-users and procedures following warnings. During critical situations, they have to support the end-users in their decision processes by providing continuously updated relevant information.

Education and training

7.17 The meeting agreed that there is a need to provide guidelines on how to use, interpret and improve very short-range forecasting tools, which should be tuned to a particular region. It therefore recommended the development of training materials, including showcases and examples on strengths and weaknesses of the various systems.

7.18 The meeting noted that within the framework of the SWFDP, training is annually provided to forecasters and end-users, and therefore agreed that very short-range forecasting tools (how to use and interpret them) should be introduced in the training programme for these events. In addition, the meeting recommended the development and use of e-learning modules on very short-range forecasting. In this context, the meeting recommended to coordinate with appropriate bodies (e.g. WSP, WWRP/CAS) in order to make them applicable for specific regions. The meeting also recommended in-country on-job training, especially in NMHSs with limited human resources (forecasters) and limited capability to pass on the training locally.

Visualization tools

7.19 The meeting agreed that in the 0- to 12-hour forecasting range, the superposition of fields is important, including the combination of observational data and model outputs, and therefore recommended the implementation of appropriate visualization tools at the NMHSs.

8. ANY OTHER BUSINESS (AOB)

8.1 There were no other issues raised during the meeting.

9. CLOSING

9.1 The Expert Meeting on Very Short-Range Forecasting closed at 13:55 on Wednesday, 23 March 2011.

Annex I

AGENDA

1. **OPENING**

2. **ORGANIZATION OF THE MEETING**
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   - 3.1 Review of the outcomes of the previous meeting (Toulouse, November 2007)
   - 3.2 Report on the outcomes of CBS-Ext.(10) related to Very Short-Range Forecasting (VSRF)
   - 3.3 Scope of the meeting

4. **DEVELOPMENTS IN APPROACHES OF COMBINATION OF NWP AND OBSERVATIONAL DATA FOR VSRF**
   - 4.1 Use of frequent and recent observations in the assimilation of NWP
   - 4.2 Blending methods of NWP output and observations
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5. **PRACTICAL APPLICATIONS AND PROJECTS**
   - 5.1 Severe Weather Forecasting Demonstration Project (SWFDP)
   - 5.2 Flash flood forecasting
   - 5.3 Organization of knowledge transfer

6. **DEVELOPING TECHNICAL GUIDANCE ON THE IMPLEMENTATION OF VSRF SYSTEMS, FOCUSED ON DEVELOPING COUNTRIES**

7. **CONCLUSIONS AND RECOMMENDATIONS**

8. **ANY OTHER BUSINESS (AOB)**

9. **CLOSING**

Annex II

LIST OF PARTICIPANTS

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Annex III

Table of possible blending approaches with model and observational data combinations for very short-range forecasting

Type	Description	Time range, availability	Examples	Documents, web sites	Remarks
Observations only	Object recognition, extrapolation (radar, satellite), data fusion	Nowcasting, immediate	TRT, RDT, gridded observations		Can be centrally produced (satellites)
Observations + model analysis	Indices	Nowcasting, immediate	GII, RII		
Superposition of observations and model	“Simple” accumulations from rain gauges and radar	SRF, immediate	Sum of rainfall until now + model from now		Simple but far to be available
Climatological Postrocessing	Comparison of model analysis or forecasts with local observations on climatological basis	SRF, available at same time as model output	Regressions, discriminance, neural networks, boosting (choice of relevant predictors),…		Non linear methods can be targeted on high impact weather
Model diagnostics	Recognition of synoptic features on NWP analysis and forecasts	SRF, available at same time as model output	Troughs, dry zones, jet streams, large scale destabilization, synoptic classification…		Synoptic recognition of high impact weather is possible
Adaptive postprocessing	Comparison of model analysis or forecasts with local observations based on recent observations and model runs	SRF, available at same time as model output	UMOS, Kalman filtering		Takes into account model changes. History usually too short to deal with rare events
Observation – model blending	Observations at initial state, model after a few hours	Nowcasting, SRF. Can be immediate if older model is used.	INCA, Scribe module		
Inclusion of local observations into specific model	Gross atmospheric conditions provided by NWP model, supplementary local data used for specific model	Nowcasting, SRF	1d models (fog, road state), 2d surface models, hydrological models		
Choice of model with the help of observations	Choice of different models or ensemble members with recent observation	SRF	Heuristic?		
Assimilation of asynoptic observations	Assimilation of radar, GPS, profiler, satellite… data into NWP model	SRF	3dVar, 4dVar, Latent heat nudging		Expensive