WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

EXPERT MEETING ON VERY SHORT-RANGE FORECASTING

Toulouse, France, 27-30 November 2007

FINAL REPORT

Executive Summary

The expert meeting took place at the Headquarters of Météo-France 27-30 November 2007 and addressed the interest expressed by CBS-Ext.(06) in operational weather forecasting in the "Very Short-Range", i.e., the implications for operational numerical processing and weather prediction systems important for forecasting in the first 12 hours of the forecasting period, which includes "Nowcasting".

Forecasting in the Very Short-range is defined in the *Manual on the GDPFS* as forecasts within 12 hours of the present, which includes "Nowcasting", defined as forecasts within 2 hours of the present. CBS also wished to address issues related to the use of emerging operational models with resolutions in the order of a few kilometres. The WMO Fifteenth Congress (May 2007) requested CBS to increase its attention to applications of NWP systems, particularly in very short-range forecasting. At the same time the current experience with the Severe Weather Forecasting Demonstration Project (SWFDP) in Southeast Africa is indicating a gap in the forecasting and provision of warning services of rapidly developing and localized phenomena such as heavy rain and strong winds associated with convective systems. This Expert Meeting focused on how forecasters should use NWP models and systems in the 0- to 12-hour forecast period.

Input and discussions included the status and GDPFS activities in WMO Regions, primarily on high-resolution limited area models, used in conjunction with available observational data, as well as relevant activities of and issues identified by the World Weather Research Programme in relation to Nowcasting. In the forecast range from the present to 2 hours, 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. During this period NWP systems need to wait for the appropriate data cut-off for assimilation and execution, as well as to permit model spin-up before results become useful. Beyond approximately the first two hours, out to 6 hours, the "blending" of high-resolution NWP outputs (less than 10-km resolution) with products based on observations is carried out, either integrated through a "forecast system", or performed subjectively by forecasters. A table of possible blending approaches was developed.

In the 6- to 12- hour forecasting range, outputs from operational high-resolution NWP models, and some down to 2-km presently in experimentation, are most important. Short-range ensembles are also used, however are not generally applicable presently in the 0 – 12-hour range, as ensemble members are generally unable to adequately quantify uncertainly (low spread) in this forecasting range.

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) from satellite-based systems, aircraft, and radar where available. The optimal use of high-resolution NWP in the 0 – 12-hour range can only be achieved with observational data, either through additional post-processing or used subjectively by forecasters. The meeting noted that many required data sets are not exchanged on the GTS. The experts encouraged the open exchange among Members of such data for use in real-time severe weather forecasting and warnings programmes.

Demonstration projects represent opportunities for comparing new technologies and techniques as wells those for operational trials to facilitate rapid and successful implementation, accounting for regional contexts and capacities (e.g. developing countries). CBS (for SWFDP) and CAS (for FDPs/RDPs) are undertaking or planning relevant demonstration projects.

The experts agreed to continue to work on issues identified, by correspondence.

1 Opening of the meeting (Agenda item 1)

1.1 The meeting was opened at the Headquarters of Météo-France at 9:30 AM, Tuesday 27 November 2007 by Mr Bernard Strauss, Deputy Technical Director of Météo-France, and Chairman of the WMO CBS OPAG on Data-Processing and Forecasting System, and welcomed the meeting on behalf of Météo-France. He briefly described the interest of CBS in operational weather forecasting in the "Very Short-Range" especially the implications for operational numerical processing and weather prediction systems important for forecasting in the first 12 hours of the forecasting period, which includes "nowcasting".

1.2 Mr Peter Chen welcomed the participants on behalf of the WMO Secretary General and recalled that CBS at its Extraordinary Session (Seoul, November 2006) noted forecasting in the Very Short-range is defined in the *Manual on the GDPFS* as forecasts within 12 hours of the present, which includes "Nowcasting", defined as forecasts within 2 hours of the present. Forecasting in the Very Short-range relies on both real-time observational data and systems, and high resolution NWP systems. CBS also wished to address issues related to the use of emerging operational models with resolutions in the order of a few kilometres. The WMO Fifteenth Congress (May 2007) requested CBS to increase its attention to applications of NWP systems, particularly in very short-range forecasting. At the same time the current experience with the Severe Weather Forecasting Demonstration Project in Southeast Africa so far is indicating weakness in the forecasting and provision of warning services of rapidly developing and localized phenomena such as heavy rain and strong winds associated with convective systems. This Expert Meeting should focus on how forecasters should use NWP models and systems in the 0- to 12-hour forecast period, including aspects of verification, as well as identify what forecasters need to improve forecasts and warning they prepare and issue.

2 Organization of Meeting

The meeting unanimously elected Mr Jean-Marie Carrière (France) to be the Chairman of the Expert Meeting. Mr Carrière is the CBS Rapporteur on the Applications of NWP to Severe Weather Forecasting.

2.1 Adoption of the agenda

The meeting adopted the agenda, as found in Annex I

2.2 Working arrangements

The meeting agreed to working arrangements of the meeting. The meeting also visited the Météo-France computing centre and the operational forecasting centre.

2.3 The meeting welcomed the input provided by all participants including those only through documents, prepared by Dr T. Keenan (Australia), and Dr Hee-Dong Yoo (Republic of Korea). The participants list is found in Annex II.

3 Introduction of Very Short-Range Forecasting

3.1 Mr Strauss provided the background to the task of the Expert Meeting. CBS recognized that in the domain of Very Short-Range Forecasting, for the period from the present to 12 hours, requires the operational implementation of relevant and emerging NWP systems to complement the use of observations-based processing systems into operational forecasting processes into this forecasting range, especially to improve severe weather forecasting. Research and development in "Nowcasting" has been making considerable advances in the recent period, including assimilation of satellite and radar data into NWP systems or the use of latest observations to further "post-process" or "downscale" the outputs of NWP systems. Severe weather forecasting, the process behind the provision of warnings services by NMHSs, is the principal focus of Very Short-range Forecasting.

3.2 The meeting was informed of the relevant text from the General Summary of:

- CBS-Ext.(06) as follows:

"The Commission noted nowcasting relies on observational data and systems, high resolution NWP and such techniques as image processing, data fusion, data analysis, extrapolation, improve high-impact weather forecasting, e.g., convective hazards (heavy rain, hail, lightning, wind gusts, etc.), winter weather events (snowstorm, blizzards, etc.) or other hazardous conditions (fog, extreme fire danger, dust storms, etc.). The complementary mix of the use of observations and high-resolution NWP to support nowcasting depends on the phenomenon, the lead-time, and actual events as they develop. Nowcasting can be implemented on a wide variety of systems and means, ranging from local treatment on a PC to the establishment of dedicated centres." (paragraph 6.3.60); and

- Cg-XV (2007) as follows:

"Congress, with the view to realizing greater benefits from Numerical Weather Prediction (NWP) systems developments, integrating real-time observational data for tracking and forecasting of hazards, requested CBS to increase its attention to applications of NWP systems, particularly in very short-range forecasting (up to 12 hours). Congress further emphasized that Members should continue investing in data-processing and use of NWP products as indispensable tools for weather forecasting, contributing directly to the WMO Natural Disaster Prevention and Mitigation Programme." (paragraph 3.1.3.2)

3.3 CBS-Ext.(06) also developed the Terms of Reference for an Expert Team on Very Short-Range Forecasting, as follows:

(a) Provide guidance on the use of NWP models and of nowcasting systems for the 0 to 12 hours' description of weather parameters, including probabilistic description, in light of the experience and progress in research;

(b) In consultation with the Coordination Group on Forecast verification:

1. Identify suitable techniques for the verification of very high resolution NWP;
2. Provide guidelines for the development of operational verification of 0 to 12 hours forecast products;

(c) Propose an update to the Manual on the GDPFS (WMO-No. 485) as required.

4 Status of implementation and exchange of NWP for Very Short-Range Forecasting

4.1 The meeting was informed about the status of operational NWP implementations relevant to Very Short-Range forecasting in various regions. Detailed information (list of titles can be found in Annex III) can be found in the reports that have been submitted to the meeting; see WMO Web site at:

http://www.wmo.int/pages/prog/www/BAS/CBS-meetings.html

4.2 Many National Meteorological Centres, some in conjunction with other national agencies, have implemented and continue to develop high-resolution (less than 10-km) limited area models (LAM) that are very relevant to forecasting in this time range.

4.3 In the forecast range from the present to 2 hours, 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. During this period NWP systems need to wait for the appropriate data cut-off for assimilation and execution, as well as to permit model spin-up before results become useful. Beyond approximately the first two hours, out to 6 hours, the "blending" of high-resolution NWP outputs (less than 10-km resolution) with products based on observations is carried out, either integrated through a processing/forecasting system, or performed subjectively by forecasters. A table of possible blending approaches with model and observational data combinations is given in Annex IV. The experts are requested to review this draft and provide comments and additions, for example references of known systems for performing the blending.

4.4 In the 6- to 12-hour forecasting range, outputs from operational high-resolution NWP models, and some down to 2-km presently in experimentation, are most important. Short-range ensembles are also used, however are not generally applicable presently in the 0- to 12-hour range, as ensemble members are generally unable to adequately quantify uncertainly (low spread) in this forecasting range.

4.5 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) from satellite-based systems, aircraft, and radar where available. The optimal use of high-resolution NWP in the 0- to 12- hour range can only be achieved with observational data, either through additional post-processing or used subjectively by forecasters. The meeting noted that many required data sets are not exchanged on the GTS. The experts encouraged the open exchange among Members of such data for use in real-time severe weather forecasting and warnings programmes.

4.6 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. Such post-processing could include statistical methods (e.g. KF, MOS), or a "specialized" 2-dimensional surface model ("CALDAS") that combines NWP outputs with additional latest in-situ surface observations and soil surface conditions and high-resolution topographical information, such as being explored for the Vancouver 2010 Winter Olympic Games (Canada).

4.7 The meeting discussed the role of WMO designated Regional Specialized Meteorological Centres (RSMC) with Geographical Specialization, in particular regarding how such RSMCs could provide NMCs of its region of responsibility with high-resolution NWP outputs, provide daily regional scale forecasting guidance, including in the 0- to 12-hour range. The RSMCs, or other centres of excellence, could be identified or designated to assist NMCs with post-processing techniques and systems to further treat NWP outputs (e.g. from RSMC) for "local" use and applications, as well as provide training on techniques or the forecasting process. These NMCs could provide timely feedback to the RSMC regarding performance, in turn forming the basis for future improvements. In this approach, there is the additional potential benefit of increasing the harmonization of warnings across national boundaries within the RSMC's region.

4.8 The meeting suggested the possibility of developing a guide or training materials on the very short-range forecasting process. In addition it considered the possibility of the development of a post-processing "tool-kit" that NMCs 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. The experts nevertheless questioned the universality of post-processing tools, and the possibly large amounts of data and significant expertise required to customize such post-processing tools in NMCs. For Least Developed Countries, therefore there is a need for the implementation of readily useable statistical post-processing tools to combine available (possibly limited) observational data sets with NWP outputs.

4.9 Verification of NWP for severe weather events, especially of very high-resolution models' outputs is a difficult challenge, and largely still in research and development. However, 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, alternative methods such as "Fuzzy" logic and scale-optimizing methods would likely be appropriate. Coordination on this matter with the CAS JWGV (Joint WWRP/WGNE Working Group on Verification) is necessary to establish operational needs, for infrequently occurring severe weather events.

4.10 The meeting noted the Status of the GDPFS NWP Centres listed by Regional Associations (Doc. INF. 4) as maintained by the Secretariat (Annex 5). While the information contained in the tables may not be entirely up-to-date, it was noted that many national centres indicated LAM implementations at relatively low resolutions (greater than 20- to 25-km), which are of the order of regional or LAM models implemented at RSMCs. Participants are encouraged to review the lists for their respective Regions and to provide updates. The Secretariat is requested to update the table with information contained in the meeting documents provided by the Regional representatives.

4.11 Some developing countries have plans to implement a high-resolution LAM to meet various national needs. In the context of short-range forecasting of severe weather, these plans should include establishing timely access to observational data, satellite and radar retrievals, and to implement processing applications that combine such data with NWP outputs (e.g. nowcasting or forecasting systems). The experts were of the opinion that while many LAMs exist today, there is generally too much confidence placed on their raw outputs by forecasters, and hence dependence on them without exercising any or sufficient meteorological judgment. In addition, the experts 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, post-processing, and verification). A alternate sustainable strategy would be to benefit from established RSMCs that could provide NWP products and services within a region of NMHSs.

5 Developments in the field of Very Short-Range Forecasting

5.1 Developments are taking place on many fronts on nowcasting technologies and in conjunction with high-resolution NWP systems, for example in most advanced

GDPFS Centres. The meeting agreed that continued developments that "cleverly" use current observational data with NWP outputs would maximize the benefits of both investments in observations and in data-processing and numerical modelling methods. In addition while the latest satellite data processing systems represent new and powerful products for forecasting in this forecast range, they need to be further developed with operational forecasting processes and forecasters in mind, especially those in developing and Least Developed Countries where weather radars are few or non-existent.

5.2 In the context of the Severe Weather Forecasting Demonstration Project in southeastern Africa, enhanced or tailored products for southern Africa from the MSG satellite system that are already available could significantly improve the forecasting of severe weather in the short-range, especially in the context of regions where radar data are not available. This improvement should be implemented in a relatively short period to result in immediate improvements in the forecasting process.

World Weather Research Programme (WWRP)

5.3 From the perspective of the WWRP, the research issues include those in Data Assimilation and Model Development, Observing Systems and Strategies, Gaps related to Uncertainty and Predictability. The WMO Commission for Atmospheric Sciences WWRP Working Group on Nowcasting Research provided the following summary of research issues on Data Assimilation and Model Development that are directly relevant to NWP in the Very Short-range including Nowcasting:

> NWP is certainly making significant and rapid gains in its capacity to undertake high resolution predictions relevant to nowcasting. This capability is extending into the realm of accurate simulations of moist storm scale evolution building on those related to dry orographic forcing which already indicate significant skill.
>
> <u>Data Assimilation (DA)</u> The challenges for convective scale data assimilation as required in nowcasting are significant and different from those encountered in larger scale NWP. Retrieval of high resolution unobserved model variables is required where observations of relevance to nowcasting are employed e.g., radial velocity observed by radar. The phenomena being forecast also have high spatial and temporal resolution without the constraint of a simple dynamical balance found in larger scale model prediction e.g., geostrophic balance. In addition the error covariance structures needed within the DA framework are not available. DA on the convective scale is still in its infancy and the best way to assimilate high-resolution data (such as from radars) into mesoscale models e.g., cloud resolving models is still an active area of research (Ensemble assimilation and 4D-VAR). The challenge lies in achieving an optimal mix of data that is representative of different scales of motion.
>
> <u>Model Resolution and Dynamics</u> To capture convective processes associated with severe weather a model resolution of less than 3-km is required with some arguing that 1-km resolution is required. For forecasting up to about 6 hours, the DA issue is crucial to account for spin-up of convection which is currently encountered in operational NWP.
>
> <u>Representation of Physical Processes</u> Strong dependencies remain on modeling physical processes within the model and as part of the data assimilation. Improvement in model physics is required but that will only

come after better understanding is achieved. Model microphysics is but one example. The representation of microphysical processes is critical in determining the timing and characteristics of thunderstorm outflows.

Model Uncertainty Error growth in the models especially at the convective scale is significant and impacts basic predictive skill. Estimating and providing "Uncertainty" of model forecasts is getting more and more important. However, there is no standard method to estimate it yet. Since model errors for mesoscale events do not fit a Gaussian probability distribution, it is not guaranteed that "ensemble method" provides appropriate estimation of model errors. Further developments are still needed in this field.

Probabilistic NWP Coupled with the advances in the physical modelling at high resolution, mesoscale ensemble based forecasts are becoming increasingly skillful. Integration of uncertainty associated with nowcasting techniques and numerical NWP is required for seamless prediction systems. For instance, 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.

Post Processing The existence of systematic biases in NWP do enable post-processing to be employed to improve the overall contribution of NWP to nowcasting. Now post-processing is being considered as an integral part of the NWP suite enabling products to be downscaled and re-gridded at standard grids relevant to nowcasting at scales beyond those involved in the original NWP run.

Forecast Systems Development and Implementation

5.4 WWRP noted the need for an integrated approach to forecast systems research and their operational implementation. The output of NWP systems is increasingly being fed directly in gridded numerical form into forecast systems. In this environment, forecasters interact with the forecast system that consists of integrated applications on workstations, which use various post-processing schemes to generate semi-automatically a range of products to meet wide variety of users' needs.

5.5 Many NMHSs have some relevant development activity in forecast systems, in particular with components directly relevant to forecasting in the Very Short-Range. The meeting believed that a suitably designed component of a forecast system could post-process jointly observational data with high-resolution NWP outputs to forecast severe weather in this range, as examples, some blending combinations, developed at the meeting, are found in Annex 4. From the development of these systems to their successful implementation requires the same level of meteorological research and technology transfer mechanism as has been applied to NWP systems. Forecast systems research needs to be closely coupled to the NWP systems at one end and to meet the operational requirements of the NMHS at the other end.

6. Relevant demonstration projects

6.1 The meeting was informed of relevant demonstration projects including those in progress and those planned for the near future, in particular the CBS Severe Weather Forecasting Demonstration Project (SWFDP), and WWRP Research Demonstration Projects (RDP) and Forecast Demonstration Projects (FDP). The meeting discussed the relevance of these projects to Very Short-Range Forecasting, as well as the differences in goals and objectives of the CBS and WWRP demonstration projects.

6.2 The meeting understood the importance of research-oriented demonstration projects, and noted that WWRP RDP/FDP tend to be “major” multi-year projects to demonstrate and test multiple technologies and to compare their relative merits and solutions to research problems. The SWFDP is intended as a short duration demonstration project for operational implementation, by creating an operations-like framework to conduct trials of existing technologies with the intention to undertake effective and optimal implementation. By this approach it is hoped that the implementation accounts for the operational realities of the targeted region, and also could be generalized by suitable recommendations of best practices.

Severe Weather Forecasting Demonstration Project (SWFDP)

6.3 The first regional subproject of the SWFDP is near completion in southeast Africa. It has successfully demonstrated the implementation of a conceptual model of the “cascading forecasting process” as well as of new products made available by global products centres and of RSMC Pretoria (South Africa), benefiting the forecasting and warnings programmes in 5 participating NMHSs in the region.

6.4 Among the conclusions already noted in progress reports is the serious lack of forecasting tools for the 0- to 12-hour forecasting period to address the forecasting problem experienced in this region of localized, sudden on-set, short-lived severe convective events that produce heavy rainfall and strong winds. There is an important need to implement nowcasting tools based on enhanced products that can be developed from retrievals from MSG satellites.

6.5 In general the SWFDP could be used to implement a series of ready-for-production enhancements to the forecasting process, such as nowcasting or new products as they become available, and also including aspects beyond forecast production such as enhancing delivery of forecast and warning services to public safety agencies, the media, and to the public. Indeed this approach could contribute to the strategy of enhancing the visibility and relevance of NMHSs in government initiatives to address disaster risk reduction in their respective territories and the larger geographic region.

6.6 The meeting was informed of the intention of RA I (Africa) to extend and expand the regional subproject as an operational activity into all of southern Africa to include 14 countries and islands of the Southern Africa Development Community (SADC), served by RSMC Pretoria, as well as to include other meteorological hazards of the region, and marine (coastal) interests, all year round. Other regional subprojects are also being considered in Africa. RA III (South America) intends to implement a regional subproject in 2008 and anticipates to include NMHSs Chile, Paraguay, Peru, Uruguay, RSMCs Brasilia and Buenos Aires, and global products centres ECMWF, CPTEC (Brazil), Offenbach DWD, and NCEP (USA), and will include severe weather forecasting aspects in the 0 – 12-hour forecasting range. RA V (South-west Pacific) also intends to explore the potential benefits from implementing a SWFDP regional subproject for the Pacific Island States, including RSMC Nadi (Fiji).

WWRP RDP and FDP

6.7 The meeting was informed of the WWRP plans for the Beijing 2008 FDP, the Vancouver 2010 FDP/RDP, the Mesoscale Alpine Programme (MAP) Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events (D-PHASE) 2007 projects. Each has research objectives relevant to nowcasting and the forecasting process for severe weather in the Very Short-range, for example in the development of suitable verification methodology from the Beijing FDP. The MAP D-PHASE, with its operational phase from 1 June to 30 November 2007, is focused on heavy precipitation forecasting as related to flooding, hence examines the coupling of high resolution NWP outputs with hydrological modelling for runoff and water levels. The project included input by around 20 NWP models, with Web-based integrated tools for model comparisons and assessment. Dr Eckert (Switzerland) demonstrated the functionality of the Web-based tools designed for registered participants of the D-PHASE project.

6.8 Developing Country Nowcasting FDP. It is proposed by both WWRP and SWFDP in Africa to develop a satellite data based nowcasting component for the SWFDP for use within Africa, or in other regions with good satellite coverage. Applicable areas include Africa, the Americas and Asia. This activity would attempt to optimize the utilization of satellite products for nowcasting in an end-to-end approach and would be built on the successful conducted during 2006-07 in southern Africa. CAS/WWRP has expressed that support from CBS OPAG on DPFS is essential for this activity to be successful. Joint WWRP and CBS planning in early 2008 is required.

7 Technical guidance on the implementation of Very Short-Range Forecasting Systems

7.1 The Chairman, also the CBS Rapporteur on Applications of NWP to Severe Weather Forecasting presented a draft document (Doc. 7(1)) 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, and when finalized will be posted on the WMO Web site as a GDPFS information or guidance document.

7.2 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 the following additional aspects:

- Verification
- How forecasters could effectively use NWP capabilities in different forecast ranges, including empirical techniques in the short-range
- Stronger emphasis on how observational data could be used in conjunction with NWP systems and outputs
- Application areas (e.g. hydrological forecasting)
- Post-processing methods
- Examples to illustrate strengths and weaknesses
- Technical issues including how to deal with large number of outputs from many NWP models

7.3 The meeting suggested that the document be kept at a general level, made available on the Web, and could include more detailed annexes (hyperlinked). In addition, it was suggested to use an alternative title, without the word "Guidelines" to more appropriately represent the information nature of the document. As well, it was suggested that the section that touches on climate forecasts be reviewed by someone with the relevant expertise.

8 Conclusions and recommendations

8.1 The meeting formulated the following conclusions and recommendations:

1. User-oriented applications of VSRF

Considering:

- The existing applications of VSRF systems in member States (soil models, one-dimensional fog models, road surface temperature models, hydrological models, etc.),
- The significant level of expertise and effort that the development of VSRF applications requires,
- VSRF systems must be targeted to meet end-user needs,

The participants were of the opinion that:

- The development of user-oriented applications of VSRF in association with end-users is highly desirable,
- Capacity building by forecasters and end-users should be conducted,
- The implementation of VSRF systems must be considered as a cross-cutting issue among research, data-processing, public weather services, and disaster management,
- The retrieval methods and retrieved remotely sensed data (precipitation estimates from radars or satellites, satellite winds, others) should be exchanged.

2. Knowledge sharing

Considering:

- The diversity of VSRF systems developed by Members,
- The need to exchange on VSRF systems,

The participants were of the opinion that:

- Production centres must be encouraged to share their knowledge and products,
- A VSRF post-processing tool kit should be built and made available to Members,
- Development of forecast systems (basic and complex) are encouraged in a coordinated way.

3. Demonstration Projects

Considering:

- The very positive results of the first SWFDP in RA I,
- The need to consider severe weather not only associated with tropical cyclones,

- The importance of considering severe weather forecasting as an end-to-end issue,
- The need to include Nowcasting time ranges in SWFDP,

The participants were of the opinion that:

- The SWFDP should be implemented in other regions, and/or expanded in a realistic and well managed fashion. An expanded follow-up project should be considered in 2008 in RA I for SADC countries with a focus on Nowcasting applications, especially satellite-based applications; another SWFDP subproject should be considered in RA III covering all time ranges from Nowcasting to Early Warning of severe weather several days in advance; and determine the feasibility and potential benefit of a subproject for the Pacific Island States in RA V,
- The feedback from users and society should be an integral part of SWFDP

4. Guidelines on VSRF

Considering:

- The need to provide guidelines on how to use and improve VSRF with a special view on high-impact weather,
- The number of existing VSRF systems, often covering the same geographical areas,

The participants were of the opinion that:

- Guidelines should be provided on the use of observations and NWP products for VSRF means, including the promotion of products to be provided by RSMCs or other centres of excellence,
- Training material should be developed for forecasters to make a good use of VSRF systems.

5. Verification

Considering:

- The necessary adaptation of verification methods to VSRF systems including very high- resolution NWP models,
- The need to develop verification methods suitable for the prediction of extreme events,

The participants were of the opinion that:

- Verification methods of VSRF systems should be investigated in coordination with CAS.

8.2 The meeting reviewed the Terms of Reference for Expert Team on Very Short-range Forecasting, as adopted at CBS-Ext.(06) and found no changes were necessary.

9 Closing of the meeting

The meeting closed at 14:00, Friday 30 November 2007.

ANNEX I

Provisional agenda

1. Opening of the meeting

2. Organization of the meeting

2.1 Adoption of the agenda
2.2 Working arrangements

3. Introduction of Very Short-Range Forecasting

4. Status of implementation and exchange of NWP for Very Short-Range Forecasting

- Status in WMO Regions
- User needs
- Issues and challenges

5. Developments in the field of Very Short-Range Forecasting

- Review of WWRP activities
- Review of the first Severe Weather Forecasting Demonstration Project (SWFDP)
- Others

6. Relevant demonstration projects

- Next SWFDP projects
- Beijing 2008
- Other activities

7. Technical guidance on the implementation of Very Short-Range Forecasting Systems

8. Conclusions and recommendations

9. Closing of the meeting

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ANNEX II

Final List of Participants

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ANNEX III

List of submitted documents

4	**STATUS OF IMPLEMENTATION AND EXCHANGE OF NWP FOR VERY SHORT-RANGE FORECASTING**	
4(1)	Short-range versions of the COSMO model, assimilation of radar data, observation model mix	RA VI - P. Eckert
4(2)	Very short-range forecasting activities within RA I	RA IV - A. Méthot
4(3)	Very short-range forecasting activities in RA II	RA II - H-D. Yoo
4(4)	Status of Implementation and Exchange of NWP for Very Short-range Forecasting in RAI	RA I - E. Poolman
5	**DEVELOPMENTS IN THE FIELD OF VERY SHORT-RANGE FORECASTING**	
5(1)	Recent advances on very short-range and short-range forecasting at Météo-France	J-M. Carrière
5(2)	WWRP: Developments in Nowcasting	T. Keenan
6	**RELEVANT DEMONSTRATION PROJECTS**	
6(1)	WWRP Demonstration Projects	T. Keenan
6(2)	Severe Weather Forecasting Demonstration Project – Contribution from RA III	R. da Silveira
INF. 3	Review of Severe Weather Forecasting Demonstration Project (SWFDP) First Quarter Progress Report of SWFDP - SE Africa	Secretariat
7	**TECHNICAL GUIDANCE ON IMPLMENTATION OF VERY SHORT-RANGE FORECASTING SYSTEMS**	
7(1)	Guidelines on the use of operational NWP capabilities for severe weather forecasting	J-M. Carrière

ANNEX IV – 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

ANNEX V

Status of Implementation of the GDPFS (Nov. 2007)

STATUS OF RSMCs AND NMCs RELATIVE TO NUMERICAL MODELS *(2005, 2006 or 2007 information)* (last update 20/11/07)

GM = Global Model
LAM = Limited Area Model
Perturbation technique for ensemble prediction systems: SV = Singular Vectors, BGM = Breeding of Growing Modes, LAF = Lagged Average Forecasts, StoP = Stochastic Physics, OP = Observation Perturbations, ETKF = Ensemble Transform Kalman Filter

REGION I

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEVELS***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
DAR ES SALAM	NMC	LAM (WRF)				GFS (NCEP)			
		LAM (HRM)				GME (DWD)			
GABORONE	NMC	LAM (WRF)				GFS (NCEP)			
		LAM (HRM)				GME (DWD)			
MAPUTO	NMC	LAM (RAMS)				(from Brazil)			
		LAM (HRM)				GME (DWD)			
ACMAD	Special Centre	access to GM							special
HARARE	Special Centre	Draught monitoring							special
LA REUNION	Tropical Cyclone (T.C.) RSMC	full access to GM					GTS	SAT	special
		full access to LAM (ALADIN)	10 km						
ALGIERS	Geographical RSMC	LAM (ETA)	36 km	24	72 h	GFS (NCEP)			
		LAM (ALADIN)	12 km	41	48 h	ARPEGE			
CAIRO	Geo. RSMC	LAM (ETA)	33 km	36	120 h	GFS (NCEP)			

		LAM nested non-hydro. (MM5)	63, 21and 7 km	36	48 h	GFS (NCEP)			
CASABLANCA	Geo. RSMC	LAM (ALADIN-NORAF)	31 km	37	72 h	ARPEGE (France)	GTS		special
		LAM (ALADIN/ALBACHIR) 3D-VAR	16 km	37	72 h	ALADIN-NORAF			
DAKAR	Geo. RSMC	LAM (ETA)	22 km	50	72 h	COLA, USA)	GTS		
		LAM (HRM)	22 km	40	72 h	GME (DWD)			
NAIROBI	Geo. RSMC	access to GM					GTS		
		LAM (HRM)	28 km	40	24 h	GME (DWD)			
		LAM (WRF)				GFS (NCEP)			
PRETORIA	Geo. RSMC	LAM (UM)	12 km	38	48 h	GM(UM) UKMO	GTS	Fax	
		GM (ECHAM) Ens. 12 members LAF	T42	L19	6 month				
TUNIS	Geo. RSMC	LAM (ALADIN)	12.5 km	L41	48 h	ARPEGE (France)			

REGION II

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEVELS***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
ABU DHABI	NMC	LAM (NCEP-ETA)	0.3°	42	72 h	GFS (NCEP)			
		LAM (NCEP-ETA-non-hydrostatic)	0.09°	42	72 h	GFS (NCEP)			
		LAM (HRM)				GME (DWD)			
BANGKOK	NMC	GM (Unified UKMO)	100 km	19	168 h				
		LAM (South East Asia)	48 km	19	72 h	GM			
		LAM (Thailand Model)	17 km	31	48 h	SE Asia			
		WRF	?	?	?	GFS (NCEP)			
HANOI	NMC	LAM (ETA)	22 km	?	48 h				
		LAM (HRM)	14 km	31	48 h	GFS (NCEP)			
HONG-KONG	NMC	LAM-(ORSM) 3 D-VAR	60 km	36	72 h	GSM (Japan-JMA)			
		MPI-ORSM 4D-VAR	20 km	40	42 h	GSM (Japan-JMA)			

		NHM – non-hydrostatic – Wind RADAR data assimilated	5 km	45	12 h	LAM (ORSM)			
KARACHI	NMCs	LAM (HRM)	28 km	40	72 h	GME (DWD)			
MACAO	NMC	LAM	54/18 km	22	60 h				
MUSCAT	NMC	LAM (ORM28)	28 km	40	78 h	GME (Offenbach)			
		LAM (ORM07)	7 km	40	78 h	GME (Offenbach)			
PYONGYANG	NMC	Hemispheric Model (HM)	T42	14	96 h				
		LAM –Regional Spectral Model	100 km	14	48 h				
		LAM	50 km	18	24 h				
SEOUL	NMC	GM (GDAPS) 3D-VAR	T426	L40	240 h				
		LAM (RDAPS)	30 km	33	66 h	GDAPS			
		LAM (RDAPS nested) non-Hydrostatic	10 km	33	24 h	RDAPS			
		LAM (RDAPS nested) non-Hydrostatic	5 km	33	24 h	RDAPS			
		Typhoon (DBAR)	0.356 °	1	72 h	GDAPS			
		GM (GBEPS) Ens. 32 (2x16 members, BGM)- LAF	T213	L40	10 days				
		GM GDAPS Ens. 20 members, BGM, 2 tier system	T106	L21	1 month, 3 months 6 months				
TEHRAN	NMC	LAM (MM5)	30 km	23	102 h				
ULAANBATAR	NMC	LAM (MM5)	80 km	35	48 h				
NCMRWF -INDIA	Special Centre	GM	T80	L18	5 days				
		LAM	50 km	18	5 days				
BEIJING	Geo. and Transport Model (T.M.) RSMC	GM (3 D-VAR)	T639	L60	10 days		GTS	SAT	
		LAM-(GRAPES)	30 km	31	48 h	GM			
		GM-(MTTP). Typhoon Track	T213	L31	120 h				
		LAM (NMC-MM5) nested, D.A. = nudging method, non-hydrostatic?	27/9/3 km	36	48 h				
		LAM Ens. 15 members, BGM	35 km	35	36 h				

		GM Ens. 15 members BGM	T213	L31	10 days				
		AGCM/OGCM	T106	L19	30 days				
		GM DERF Ens. 40 members 16 SV, 16 LAF coupled, Ocean	T63 GT63	L16 L30	1 month				
		GM Ens. 48 members LAF coupled 8 atmo x 6 oceano cond.(perturb ocean) Ocean	T63 GT63	L16 L30	Season				
JEDDAH	Geo. RSMC	LAM (HRM)	48 km	48	48 h	GME (DWD)			
KHABAROVSK	Geo. RSMC	LAM	50 km	15	48 h				
NOVOSIBIRSK	Geo. RSMC	LAM (Sib- SRHMS)	50 km	15	48 h				
TASHKENT	Geo. RSMC								
NEW DELHI	Geo. and T.C. RSMC	full access to GM (NCMRWF)					GTS		
		LAM (LAFS) 3-DVAR	0.75°	16	48 h	NCMRWF			
		For TC: Quasi-Lagrangian model 3 D-VAR	40 km	16	36 h				
TOKYO	Geo.- T.M. and T.C. RSMC	GM (GSM0305) 4D-VAR	T319	40	216 h		GTS		special
		LAM (RSM0404) 4D-VAR	20 km	40	51 h	GSM			
		LAM (MSM0603) 4 D-VAR, non-hydrostatic	5 km	50	15 h	RSM			
		GM Ens. 51 members BGM	T159	40	9 days				
		GM Ens. 50 members 25 BGM and 25 members LAF on 2 days	T106	40	34 days				
		GM Ens. 51 members, SV, 2 tiers for SST	T63	40	4 months				
		GM Coupled (AGCM/OGCM) Ens. 31 members, SV	T42	40	18 months				
		Typhoon (TYM0306)	24 km	25	84 h	GSM			

REGION III

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEVELS***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
BOGOTA	NMC	LAM (MM5)	25 km						
LIMA	NMC	LAM (ETA)	48 km	36	120 h	GFS (NCEP)			
		LAM (ETA-SENAMHI))	25 km	38	120 h	GFS (NCEP)			
		CCM3 En. 12 members, SST (forecast by NCEP and perturbed)	T42	L32	9 months	SST, USA			
QUITO	NMC	LAM (MM5)	25 km						
SANTIAGO	NMC	LAM (MM5)	60 km		60 h	GFS (NCEP)			
		LAM (MM5)	20 km						
INPE/CPTEC -SAO PAULO	Special Centre	GM AGCM CPTEC/COLA	T170	42	15 days	GFS (NCEP)			Special
		GM AGCM Ens, 15 members (Random OP)	T126	L28	15 days	GFS (NCEP)			
		LAM (ETA)	40 km	38	120 h	GFS (NCEP)			
		GM Coupled, Ens. 30 members (Random OP)) Fixed and predicted SST	T62	28	Six months	GFS (NCEP)			
BRASILIA	Geo. RSMC	full access to GM					GTS		
		LAM (MBAR-HRM)	25 km	35	48 h	GME (Germany)			
BUENOS AIRES	Geo. RSMC	LAM (ETA SMN)	25 km	38	132 h	GFS (NCEP)	GTS		

REGION IV

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
SAN JOSE	NMC	LAM (ETA)	10 km		36 h	GFS (NCEP)			
		MM5				GFS			
IRI (USA)	Special Centre	Ens. multi-models, over 30 members, LAF			6 months				
MEXICO	NMC	LAM (MM5) non-hydrostatic	45km	20?	72 h	GFS			
MONTREAL	Geo. and T.M. RSMC	GM (GEM) 4D-VAR	33 km	58	240 h and 360 h		GTS		
		GM Ens. 16 members (Random OP, 96 ETKF analyses and two models running on 8 members)	T149 and 1.2 deg.	28	360 h				
		GM (GEM Regional) 3-D VAR	Variable mesh 0.22° (~ 15 km)	58	48 h				
		LAM (HIMAP)	10 km	35	30 h				
		GM Ens. 40 members (24 h LAF, four models)	1.875° T32	50 10	9 months				
MIAMI	Geo. and T.C. RSMC	full access to GM and LAM						SAT	
		HCN (hurricane)	0.16°	18	72 h				
WASHINGTON	WMC/ Geo. and T.M. RSMC	GFS (3D-VAR)	T382	64	84 h		GTS	ISCS (WAFS)	Special
			T170	42	84 to 180 h				
			T126	28	180 to 384 h				
		LAM (RUC)	40 km	40	12 h	GFS			
		LAM (NGM)	90 km	16	48 h	GFS			
		LAM (NAM) 3D-VAR (Meso-ETA) over Alaska	60 km	60	84 h	GFS			

		LAM ((HiRes) 3D-VAR (Meso-ETA)	12 km	35	48 h	GFS			
		LAM ((HiResM) 3D-VAR (Meso-ETA) over some regions	5.1 km	35	48 h	GFS			
		Hurricane	0.5 deg.	42	120 h	GFS			
		Regional Ens. 15 members (10 ETA +5 RSM) (SREF) (North America) (BGM)	48 km	60	63 h				
		Global Ens. 20 members (GFS)	T126 T62	28	84 h 85 h to 16 days				
		Ens. 20 members, (GFS) coupled, Modular Ocean Model ,MOM 3, LAF	T62 1/3-1deg.	64 40	7 months				

REGION V

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV.***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
JAKARTA	NMC	LAM (MM5) non-hydrostatic	50km, 30km, 5-10 km	23	72 h	GFS (NCEP)			
KUALA-LUMPUR	NMC	LAM (MM5-RAPS)	36 km	23	72 h	CMA			
			12 km	23	72 h				
MANILA	NMC	LAM (MM5)	20 km	36	72 h	GFS (NCEP)			
		LAM(HRM)	?	?	?	GME(DWD)			
SINGAPORE	NMC and ASEAN Specialised Meteorological Centre (ASMC)	GSM	1.875°	16	240 h				special
		LAM (FLM)	127 km	12	72 h	GSM			
		LAM (VFM)	63.5 km	13	72 h	GSM			
DARWIN	Geo. RSMC	full access to GM							

		LAM-(TLAPS)	0.375°	19	48 h		GTS	SAT	special
NADI	T.C. RSMC	Access to GM					GTS		
WELLINGTON	Geo. RSMC	LAM		8	h				
MELBOURNE	WMC, Geo. and T.M. RSMC	GM (GASP) OI-1D-VAR	T239	33	240 h		GTS	SAT	special
		LAM (LAPS)	0.375°	29	72 h	GASP			
		LAM (TX-LAPS)	0.375°	29	72 h	GASP			
		LAM (MESO-LAPS)	0.125°	29	36 h	LAPS			
		LAM (5 domains in South)	0.05°	29	36 h	LAPS			
		TC-LAPS	0.15°	29	72 h	GASP			
		Ens. GM, GASP -EPS, 33 members, SV (GASP-EPS)	T119	19	10 days				
		Ens. 30 members, GM coupled (POAMA), LAF	T47	17	10 months				

REGION VI

							DISSEMINATION		
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEVELS***	***RANGE***	***Boundary***	***GTS***	***SAT.***	***SPECIAL***
ANKARA	NMC	full access to GM (ECMWF)							
		MM5V3	21 km	32	48 h				
		MM5V3	7 km	32	48 h	Nested			
ATHENS	NMC	full access to GM (ECMWF)							
		LAM (ETA-NMC) nudging	0.1°	32	72 h	ECMWF			
		LAM (LM) non hydros..	0.0625	40	48 h	GME			
		LAM (RAMS) nested, non hydros.	48 km, 12 km, 3 km°	32	36 h	ECMWF			
BELGRADE	NMC	LAM-(ETA 95) 3D-VAR	52 km	32	120 h	GME (Offenbach)			
		LAM (ETA)	18 km	64	48 h	ECMWF			
BET DAGAN	NMC	LAM (HRM)	13 km	38	78 h	GME (Offenbach)			

BRATISLAVA	NMC	LAM (ALADIN/ SLOVAKIA)	9 km	37	54 h	ARPEGE			
BRUSSELS	NMC	full access to GM (ECMWF)							
		LAM (ALADIN)				ALADIN (France)			
BUCAREST	NMC	LAM (HRM)	20 km	20	78 h	GME (Offenbach)			
		LAM (MM5)	15 km	25	24 h	GFS (USA)			
		LAM (ALADIN)	10 km	41	48 h	ARPEGE (France)			
BUDAPEST	NMC	LAM (ALADIN/HU) – 3 D-VAR	8 km	49	48 h	ARPEGE (Toulouse)			
COPENHAGEN	NMC	full access to GM (ECMWF)							
		LAM (DMI-HIRLAM-T15) 3D-VAR	0.15°	40	60 h	ECMWF			
		LAM (DMI-HIRLAM-S05)	0.05°	40	54 h	T15			
DE BILT	NMC	full access to GM (ECMWF)							
		HIRLAM	0.5°	31	48 h				
DUBLIN	NMC	full access to GM (ECMWF)							
		LAM (HIRLAM) 3D-VAR	0.15°	31	48 h	ECMWF			
HELSINKI	NMC	full access to GM (ECMWF)							
		LAM (RCR-HIRLAM) *	0.2° (22 km) 3 D-VAR	40	54 h	ECMWF			
		LAM (MBE)	0.08° (9 km)	40	54 h	RCR			
KIEV	NMC	LAM							
LISBOA	NMC	LAM (ALADIN-Portugal)	12.7 km	31	48 h	ARPEGE-Meteo-France			
LJUBLJANA	NMC	LAM (ALADIN)	11.2 km	37	48 h	ALADIN/LACE			
MADRID	NMC	full access to GM (ECMWF)							
		LAM (HIRLAM)	0.5°	31	48 h				

		LAM (HIRLAM)	0.2°	31	24 h				
		LAM (HRM)				GME (Offenbach)			
MINSK	NMC	LAM	75 km	15?	48 h	Moscow			
NORRKOPING	NMC	full access to GM (ECMWF)							
		LAM (HIRLAM) 3 D-VAR (C-22)	22 km	40	48 h				
		LAM (HIRLAM) E-11	11 km	60	48 h	C-22			
		LAM (HIRLAM) F-05	5 km	60	48 h	E-11			
OSLO	NMC	full access to GM (ECMWF)							
		LAM (HIRLAM)	0.5°	31	48 h				
		LAM (HIRLAM)	0.1°	31	48 h				
PRAGUE	NMC	LAM (ALADIN)	9 km	43	54 h	ARPEGE-			
RIGA	NMC	LAM (HIRLAM 2)	55 km	16	36 h				
SKOPJE	NMC	LAM (NMM) non-hydrostatic				GSM NCEP			
SOFIA	NMC	LAM (HRM)	9 km	31	48 h	GME (Offenbach)			
		LAM (ALADIN)	12 km	41	48 h	ARPEGE			
VIENNA	NMC	LAM (ALADIN-AUSTRIA)	9.6 km	45	72 h	ARPEGE-			
		Ens. 22 members LAM ALADIN-LAEF – SV	18 km	37	54 h	ECMWF-EPS			
WARSAW	NMC	LAM (COSMO-LM)	14 km	35	78 h	ECMWF			
		LAM (ALADIN)	13.5 km	31	48 h	ARPEGE-			
ZAGREB	NMC	LAM (ALADIN)	8km	37	54 h	ARPEGE-			
		LAM (ALADIN)	2km	37	54 h	ARPEGE-			
ZURICH	NMC	full access to GM (ECMWF)							
		LAM (LM – COSMO consortium) non-hydrostatic, nudging	7 km	45	72 h	IFS (ECMWF-BC)			
ECMWF	RSMC for Medium-Range	GM (IFS) 4D-VAR	T799 (about 25 km)	91	240 h		GTS		special

		GM (IFS) Ens.- 50 members SV+StoP	T399 T255	62 62	240 h 10 to 15 days				special
		GM (IFS) Ens. 50 members SV+StoP, coupled with HOPE (Hambourg Ocean Primitive Equation) , 5 ocean OI analyses with SST perturbation	T159 zonal resol. 1.4 deg.	62 29	10 days to 1 month				special
		GM (IFS) Ens. 41 members OP+StoP, coupled with HOPE , 5 OI ocean analyses with SST perturbation	T159 Zonal resol. 1.4 deg	62 29	7months 4 times a year 13 months		GTS, SST available in GRIB 2		special
OBNINSK	T.M. RSMC (for RA II)	full access to GM – HM and LAM							
TOULOUSE	T.M. RSMC	GM (ARPEGE) (4 D-VAR)	Variable mesh T358C2. 4 23 km to 133 km	46	102 h			SAT-RETIM	special
		GM (ARPEGE-Tropics- Indian Ocean)	T358	41	72 h				
		PEARP 11 members, SV on Atlantic and Western Europe	T358 var mesh 2.4	41	60 h	ARPEGE			
		LAM (ALADIN)	9 km	41	54 h	ARPEGE			
		LAM (ALADIN Trop. Cyclone-Indian Ocean))	31 km	41	72 h	ARPEGE			
		GM (ARPEGE-Climat) Ens. 10 members – LAF Coupled OPA8.2	T63	31	129 days				
		GM (ARPEGE-Climat) Ens. 41 members – LAF Coupled 8 atmos. X 5 ocean initial stes	T63	31	16 months				

EXETER	Geo. and T.M. RSMC	GM (Unified Model) 4D-VAR non-hydrostatic	40 km	50	144 h		GTS	SADIS (WAFS)	
		NAE -North Atlantic European 4 D-VAR	12 km	70	48 h	GM			
		LAM 4D-VAR non-hydrostatic Some RADAR data nudging	4 km	70	36 h	GM			
		Ens. 24 members GM, ETKF 2 stoc.physic	90 km	50	72h				
		Ens. (MOGREPS). 24 members.	24 km	70	36 h	GM. Ens.			
		GM Had CM3 Glosea Ens. 41 members, coupled, OI ocean, 40 random OP of SST	Atm. 2.5° Ocean: 1.25°	19 40	6 months				
OFFENBACH	Geo. RSMC	GM (GME) 3 D-VAR	40 km	40	174 h			DWD-SAT	special
		LAM (COSMO-E – nested in GME- non-hydrostatic) nudging	0.0625° (7 km)	40	78 h				
		COSMO-K	2.8 km	50	21 h				
ROME	Geo. RSMC	full access to GM (ECMWF)							
		LAM (EuroHRM 3 D-VAR)	28 km	31	72 h	BC ECMWF			
		LAM (EuroLM)	7 km	31	48 h	Euro-HRM			
		LAM (LAMI) non-hydrostatic (run in Bologna) nudging	7 km	35	72 h	GME (DWD)			
MOSCOW	WMC, Geo. RSMC	GSM 3D-OI	T85	31	240 h		GTS		
		LAM	75 km	30	48 h	GSM			
		LAM (non-hydrostatic)	10 km	15	36 h	LAM			
		GM Ens. 10 members, two-tier, OI ocean, Semi-Lagrangian AGCM..	1.125°/ 1.40625°	28	4 months				

GROUP OF COUNTRIES					
(ALADIN consortium): Austria, Belgium, Bulgaria, Croatia, Czech Republic, Hungary, Morocco, Poland, Portugal, Romania, Slovakia, Slovenia, Tunisia	LAM (ALADIN)	12 km	31	48 h	ARPEGE-Meteo-France
HIRLAM (HIgh Resolution Limited Area Model): Denmark, Finland, Iceland, Ireland, The Netherlands, Norway, Spain and Sweden	LAM (HIRLAM)				ECMWF
COSMO_LEPS: Germany, Greece, Italia, Poland, Romania, Switzerland	LAM non-hydrostatic nested in ECMWF EPS model, 16 Ens. members. selected from 102 ECMWF ens. members	10 km	32	120 h	
The German Lokal Modell (LM) is used operationally at the national meteorological services of Greece, Poland, Romania and Switzerland and at the Regional Meteorological Service in Bologna (Italy),					
The hydrostatic high-resolution regional model HRM of the DWD is being used at fifteen national/regional meteorological services, namely Brazil-INMET, Brazil-Navy, Bulgaria, China, Israel, Italy, Kenya, Oman, Pakistan, Philippines, Romania, Senegal, Spain, United Arab Emirates and Vietnam. For lateral boundary conditions, GME data are sent via the Internet to the HRM and LM users.					

- COMPUTERS USED FOR DATA PROCESSING AT RSMCs AND NMCs -

REGION I

CENTRE	*MAINFRAME (number cruncher)*	*SECONDARY COMPUTER(S)*	**WORK STATIONS**
ACMAD		INTEL based servers (AMEDIS system) – SUN SPARC	PCs
GABARONE		PC cluster	
HARARE			IBM PSs - PCs
ALGIERS		PC Pentium IV	30 PCs
CAIRO	IBM S/390	4 HP 750C	12 IBM PC 300 GL, 18 PC Pentium
CASABLANCA	IBM RS 6000 SP	SUNSPARK 1000	SGI - 3 DEC ALPHA - MOTOROLA
DAKAR			PCs
MAPUTO		HP wx 9300, Dell Precision 470n	
NAIROBI		PCs Pentium III, VAX3900 – VAX 11/750	SGI – PCs
LA REUNION			Work Stations
PRETORIA	NEC SX8	2 SGI Origin 200, 2 SGI Indigo –- SUN Enterprise 3000	PCs
TUNIS	Super calculator	2 DELL Xeon, HP715/80, HP 755/80	

REGION II

CENTRE	*MAINFRAME (number cruncher)*	*SECONDARY COMPUTER(S)*	**WORK STATIONS**
ALMATY			PCs
BANGKOK	IBM RS/6000SP 12.96 GFlops	2 RS 6000 595	WKs
HANOI		PC Cluster	
HONG-KONG	IBP p630 cluster (16 processors) 76.8 GFlops, IBM p690 (20 processors) 88GFlops, IBM RS/6000 SP (44 processors) 66 GFlops	CRAY SV1-1A (16 processors), SGI Origin 2000, 2 SUN E450, 2 SGI O2	WSs
KARACHI		GRID RAK HP	PCs
OMAN	SUN E4500 12 processors and E4504 processors		

PYONGYANG		Pentium III	PC/AT – PS/2
SEOUL	CRAY X1E-3/192-L (15.75 TFlops), 2 CRAY X1-3/192-L (635 GFlops) NEC SX-5/28M2, SX-4/2A	HP V2500 (48PE)	SUN 2000
TEHRAN	2 PC Cluster Systems 8 and 32 Nodes	IBM 370 (2x 4381)	PCs
ULAANBATAR		PC Cluster System	MICRO VAX 3400
NCMRWF-INDIA	CRAY XMP/216		DEC Alpha WSs, SUN Ultra Sparc II WSs, SGI ORIGIN 200 and O2 WSs
BEIJING	IBM CLUSTER 1600 (20 TFLOPS) IBM SP RS6000 NH1 SP (71 GFLOPS)	IBM SP2/32	WSs
JEDDAH		CDC CYBER 962 – 2 CDC 910	3 SG – 4 VAX – 3 CDC
KHABAROVSK		XEON-2, COMPAREX, COMPLEX GIS Meteo	PC Pentium IV, PCs
NOVOSIBIRSK	CRAY EL	XEON-2	PCs
TASHKENT		HP 9000	PCs
NEW DELHI	CDC CYBER 2000U	SGI ORIGIN 200, 2CDC 4680	2 VAX 11/730, WS: 4 CYBER 910-485, VAX 3400, 5 Pentium II
TOKYO	HITACHI SR11000/K1 E1/80 nodes	3 HITACHI 8000	HITACHIs

REGION III

CENTRE	*MAINFRAME (number cruncher)*	*SECONDARY COMPUTER(S)*	**WORK STATIONS**
LIMA	Clúster Beowulf 30 nodes, Pentium IV , IBM XP 1000	3 COMPAQ Alpha ES 40, 3 Alpha DS20, Alpha XP100	
SANTIAGO		HP E800	8 Sun Ultra 1/40
INPE(CPTEC - SAO PAULO)	NEC SX 6/32M4, NEC SX 4/8A	2 SUN 280 R, 1 SUN FIRE 6800	62 WSs (DEC, Compaq), 41 PCs
BRASILIA	SGIs	2 DEC Alpha 3000-300	WSs (10): DECs, SGIs

BUENOS AIRES		SGI Origin 2004 and SGI Impact 10000	3 SGI Challenge S SGI INDIGO IMPACT – WSs

REGION IV

MEXICO		SGI Origin 2000	
MIAMI			WSs
MONTREAL	IBM P Series 690 (960 CPU) IBM P Series 575 (256 CPU)	2 SGI Origin 3000, 1 SGI Origin 300; 1 TANDEM Himalaya	55 Dell, 61 Compaq DL
WASHINGTON	IBM CCS (2816 processors)	2 SGI Origin 2000/32, SGI ORIGIN 3000/16	

REGION V

CENTRE	*MAINFRAME (number cruncher)*	*SECONDARY COMPUTER(S)*	**WORK STATIONS**
JAKARTA		PCs Cluster	
KUALA-LUMPUR	TX 48, GX 28	HPJ5600	
MANILA		PCs Cluster SGI ORIGIN 2000	
SINGAPORE	NEC SX-6	2 FUJITSU M1600, FUJITSU DS90s, 8 SGI Origin 2000	WKs SGI Octane/O2/Indy, PCs
DARWIN			WSs
NADI		2 IBM RS6000/J50	WSs, PCs
WELLINGTON		ALPHA- 9 PARALLEL PROCESSORS.	WSs
MELBOURNE	NEC SX-6 Multi-Nodes (28) 8 cpu/node	NEC TX7/i9510, 9 HP, 2 IBM p690, 2 SGI, 8 DELL	

REGION VI

CENTRE	*MAINFRAME (number cruncher)*	*SECONDARY COMPUTER(S)*	**WORK STATIONS**
ANKARA	IBM pSeries 690	SGI Onyx 2, SGI 2200, 3 IBM p630	INTEL P4, PCs
ATHENS	IBM Cluster 1600 28 Computer Nodes 7039-651 pSeries 655	8 RX 2600 6 RX 5670	Sun Clúster WSs - PCs

BELGRADE		Beowulf Cluster	37 PC Pentium
BET DAGAN		SGI Origin 350 300, 2xSGI Origin 200	8 SGI WSs
BRATISLAVA	IBM P690 32 processors	HP 9000/720, IB p470, p460	HPs
BRUSSELS	CRAY J916	HP servers	WSs
BUCAREST	SUN: E4500-8 processors, SUN E3500 –4 processors, Blade1000 – 1 processor	DEC-ALPHA 5004 SUN-ULTRA (2 processors), HP servers	PCs
BUDAPEST	IBM Regatta p655 cluster server (32 processors), p690 Server with 32 processors, SGI ALTIX 3700	SGI Origin 2000 (16 procesors) HP L3000 HPs, DEC 600	HP, DEC, SUN WS - PCs
COPENHAGEN	NEC-SX6 (8 nodes x 8 processors) 2 NEC TX 7	4 SGI Origin 200	WSs
DE BILT		SGI Power Challenge, SGI Origin 2000	Compaq clusters - WSs
DUBLIN	IBM RS/6000 SP	2 SGI Origin 200, SGI CHALLENGE L–2 VAX 4200 – VAX 3100	
HELSINKI	SGI ALTIX 3700, SGI Origin 2000	VAX 6240	VAX Clusters - WSs
KIEV		EC-1061	PCs
LISBOA		2 DEC Alpha 2000 4/275, 2 DEC Alpha XP1000	
LJUBLJANA	14 dual processors nodes		PCs
MADRID	CRAY C-94	VAX – HP/HPUX and SUN/SOLARIS	SUN WSs
MINSK		2 Intel Celeron 600	3 Intel PIII, 2 Intel P-II
NORRKOPING	CRAY T3E (232 processors) (shared), BLIXT XEON 3.2	Linux Cluster, SGI 3800 DEC Alpha servers	29 VAX (Clusters) - 7 DEC – SUN WSs
OSLO	CRAY T3E	2 IBM RS6000 3 SGI Origin 2000, 200	VAX 4000-200/3300 DEC3100 Alpha-200
PRAGUE	NEC SX-6/4B-32	Fujitsu/ ICL DRS6000	SUN SPARC 10/512, 2 TWO , 10 ONE WSs
RIGA		VAX 3400	WSs
SOFIA	CYBER 31 FLOP1	MOTOROLA SYSTEM	
VIENNA	NEC SX-8R	SGI Origin 3400 28 processors	
WARSAW	SGI Origin 3800	SGI 2000	PCs
ZAGREB	SGI ALTIX	SGI Origin 3400 , 16 CPU	
ZURICH	NEC SX-5 (shared)	8 processors SGI O3000	WSs
ECMWF	2 IBM 1600+ Clusters, 2x2480 processors (1.9GHz Power5+)	11 IBM pseries 4 HPrx4640	SGIs, PCs

EXETER	NEC SX, NEC 19X	IBM Z990, Z800, 11 IBM Pseries, 4 HP rx 4640	HP WKs
TOULOUSE	NEC 5X 8R 31	HP RP4440, HP T600, HP D370, HP K580	
OFFENBACH	IBM p575 cluster 48 nodes equipped with 8 Power5 processors each IBM p690 Server / p615 Server	Sun Fire 4900 Server 4 SGI ORIGIN 2000	SGI WSs
ROME	ECMWF Service Computer type: IBM-P690 1-4 nodes 30/120 processors.	COMPAQ ES 45, DS 10, GS 60E, 4 HP Alpha server	HP WSs
MOSCOW	CRAY Y-MP8E, 4 XEON	CRAY Y-MPEL 98 – COMPAREX 8/83	2 HP 735 WSs